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The Thermal Springs of Bockfjord, Svalbard - Hydrochemical Data Report

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The Thermal Springs of Bockfjord, Svalbard - Hydrogeochemical Data Report

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In July 1996, a team of researchers visited the "Troll" and "Jotun" springs of northern Svalbard to carry out mapping and sampling activities.

The main conclusions of the hydrochemical survey will be reported in scientific articles in the journals "Geothermics" and "NGU Bulletin". This report serves to document the data used in these articles and to present an unpublished assessment of analytical techniques applied to the trace element geochemistry of solid (rock and travertine) samples.

Emneord: Hydrogeologi	Grunnvannskjemi	Kilder
Fjell	Prekambrium	Devon
Geotermisk energi	Svalbard	Fagrapport

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1. FOREWORD

The following text is based on an expanded version of an article submitted to the journal Geothermics and due for publication in 1998.

The Appendices document the raw hydrochemical and geochemical data from the investigation, and present the data in the form of x-y plots and boxplots produced using the geochemical statistical and visualisation software, DAS.

2. INTRODUCTION

The two groups of thermal springs at Bockfjord, the Troll springs and the Jotun springs (Fig. 1), at almost 80°N latitude on Svalbard, probably represent the northernmost documented subaerial thermal springs in the World. In July 1996 a multidisciplinary team of scientists visited the spring sites to examine the hydrochemistry, flow regime, isotopic composition, geological situation and microbiology of the springs with the following objectives:

(i) to document and understand a unique natural phenomenon which, although currently in a near-pristine state, is likely to become increasingly visited by tourists and scientists in the near future (Høgvard et al. 1997).
(ii) to increase our understanding of groundwater recharge and discharge processes in deeply permafrosted terrains (see e.g. Lauritzen 1991, Haldorsen & Lauritzen 1993).
(iii) to explore novel ways of obtaining information on past climatic variations on Svalbard from the isotopic signature preserved in the springs' travertine deposits.

This report seeks to document the hydrochemistry of major and selected minor elements in the spring waters, together with possible geothermometric interpretations of the waters' composition. Future papers will address the trace element and isotope chemistry of the waters, host rocks and travertine deposits, and the interpretation of the hydrogeological regime.

3. THE THERMAL SPRINGS OF SVALBARD

In a permafrost terrain, where the annual average surface temperature is < 0°C, any persistent groundwater spring may be regarded as thermal according to strict definitions. There are typically three types of springs on Svalbard:

Type 1: during summer, melting of permafrost in the active layer leads to the creation of very shallow groundwater systems and springs, discharging at temperatures of near 0°C.

Type 2: springs derived from systems of sub-permafrost groundwater. Under much of Svalbard, permafrost may exceed 300 m thickness (Orvin 1944). Groundwater recharge is believed to take place below warm-based glaciers, where permafrost is absent (Liestøl 1976, Lauritzen 1991, Haldorsen & Lauritzen 1993, Lauritzen & Bottrell 1994). Groundwater flows beneath the thick permafrost layer to discharge at springs, which may be high discharge karstic springs or low discharge springs which may form pingos, where there are open taliks in the permafrost. The location of the base of the permafrost and the temperature of the groundwater depend on a complex interplay of several factors such as surface climate and topography, geothermal heat flux, groundwater flux and frictional heat generated by groundwater flow. Lauritzen (1991) and Haldorsen & Lauritzen (1993) note that much sub-permafrost groundwater discharges at temperatures of around 4 °C.

Type 3: Svalbard boasts a number of springs which are more impressively thermal, often with significant discharges (Orvin 1944). Examples of H_2S-rich, saline springs with temperatures of up to 15°C were described at Fisneset ('Fart Point') by Lauritzen & Bottrell (1994). These lie on the Hornsund fault zone of Southern Svalbard and the salinity appears to be derived from a deep thermal brine rather than modern sea water. The Troll and Jotun springs bear many similarities to the Fisneset springs but lie much further north and are considerably hotter.

4. THE BOCKFJORD SPRINGS

4.1 History

The springs are believed to have been documented first in the late 19th century, and they are described in some detail by Hoel & Holtedahl (1911, 1913) and Hoel (1914). These authors measured water temperatures of 24.5°C at the Jotun springs and up to 28.3°C at the Troll springs. They also provide details of some chemical analyses performed at that time (Table 1), which are of interest in comparison with the current analytical suite. Hoel and Holtedahl (1911) also observe that the waters are of dominantly sodium bicarbonate character.

4.2 Geological Setting

The springs occur almost on the line of a major fault which appears to follow the western shore of Bockfjord. The fault has a large downthrow on the eastern side and forms the western boundary of a major graben structure, bringing the Devonian 'Old Red' sandstones and siltstones of the Wood Bay formation into contact with the Precambrian Hecla Hoek complex (Gjelsvik 1979, Hjelle 1993). The Hecla Hoek consists of a ca. 2 km wide outcrop of limestone and dolomite marbles in the east (adjacent to the fault), overlying a thick sequence of gneisses and migmatites further west. The complex also includes phyllites, mica schists and metadolerites and is believed to be of mid-late Proterozoic age.

The Troll springs appear to emerge from brecciated fine-grained marbles of the Hecla Hoek complex, although an apparent outcrop of greenish basal Devonian sandstones can be observed in the shoreline several tens of metres east of Troll Spring Area 1. The geology of the Jotun Spring area is more difficult to interpret. Outcrops of Hecla Hoek marble are found a short distance below the springs although much of the frost-shattered material immediately around the springs is mica schist, also from the Hecla Hoek. Gee & Moody-Stuart (1966) describe the occurrence of Devonian sandstones on the coast north of Sverrefjellet.

The Bockfjord area exhibits significant evidence of geologically recent crustal uplift, mantle lithosphere thinning and volcanism (Vågnes & Amundsen 1993). The main phase of uplift and volcanism was in the Neogene, resulting in tholeiitic basalt caps to several of the mountains around Bockfjord. A later phase of alkaline olivine basalt and breccia eruption occurred near Bockfjord in the Quaternary, most notably from the volcanic centre of Sverrefjell, between the Troll and Jotun springs (Fig. 1). The volcanic centres of Sverrefjell and Sigurdfjell also lie on the same graben boundary fault as the springs. These volcanoes may have been active as recently as the last interstadial (Skjelkvåle et al. 1989).

Vågnes and Amundsen (1993) suggest a geothermal heat-flow anomaly extending south from Yermak to Bockfjord, with a heat flow at Bockfjord of some 130 mW m^{-2}. Xenolithic evidence from Quaternary volcanism at Bockfjord suggest temperatures of 550°C at 7 km depth (Amundsen et al. 1988), corresponding to an average temperature gradient of some 0.079 °C/m.

The age of the springs themselves is unknown. W.B. Harland and M.J. Hambrey are recorded by Langangen (1979) as opining that the springs are unlikely to be older than 4-6500 years. However, if Liestøl (1976) is correct in his theory that many springs and pingos on Svalbard first formed below sea-level, the springs might be older. They might even be as old as the volcanoes and may have formed subglacial spring outlets during the maximum of the last glaciation, as well as submarine spring outlets during the periods of high sea-level.

The Troll springs can be seen to occur below a fossil shore line and at the same topographic level as apparently marine clays. One should not, however, conclude that the springs only became 'activated' on their post-glacial emergence from the sea. It is also possible that the springs may have survived marine inundation at times of higher sea-level; submarine thermal springs are known today from the Tempelfjord area of Svalbard (Hoel and Holtedahl 1911, 1913).

4.3 Spring Morphology

The mountains to the south and west of Bockfjord are heavily glaciated. Lobes of glacier extend down almost to sea-level at the southern ends of Bockfjord and Woodfjord, with associated terminal moraine complexes and sandurs with braided river systems. Smaller glacial lobes also extend almost to sea-level from side valleys along the western side of Bockfjord.

There are six discrete areas of travertine deposition associated with groups of active thermal springs at the Troll springs area. The spring areas are numbered 1 to 6 from the south. The springs typically deposit wide shallowly concave basin complexes of travertine, each basin with a low wall. The hottest waters emerge at the top of the basin complex (the so called 'A'-position - Fig. 2) and cascade down through the basin complex, often seeping into the travertine near the base of the complex. Below the basin complex sheets of massive travertine breccia tend to occur. This presumably represents frost-shattered material cemented by the carbonate-saturated thermal groundwaters seeping through it. The thermal waters may re-emerge on their way down to the fjord at 'B'- and 'C' positions or they may not re-emerge until the level of the sandur at the southern end of the fjord ('D' position). The spring nomenclature is such that 3A2 means 'the second spring of the third spring area from the south, A-position spring'.

The top of the travertine deposits of Spring Area 6 is topographically higher than areas 1-5, but no active spring emerges from the A-position. Two thermal springs emerge lower down the travertine deposits in what is strictly a 'B'-position. As these are highest level waters of spring area 6, these are, for the purposes of this paper, designated 6A1 and 6A2.

A seventh fossil spring area is observed between areas 5 & 6 at a considerably higher topographic level. It is argued that the two northern Spring Areas (6 and 7) were once active at times of greater groundwater head in the thermal system enabling travertine systems to develop at a higher topographic level than today. It is of course possible, that the effect is due to post glacial emergence of the Svalbard coast and the actual head relative to sea-level has not changed. Nevertheless, in several spring areas, the size of the travertine basin complexes often appears disproportionately large relative to the size of the current springs. This would indicate that groundwater heads and flow have genuinely been larger in the past, a conclusion supported by Hoel & Holtedahl (1911, 1913).

The Jotun springs have not developed any terraced travertine basins. They have rather developed huge convex mounds of travertine. At Spring Area 1 (east), three small springs (1JA1-3) emerge from the flattened top surface of the mound. At Spring Area 2 (west), no springs emerge from the top although one emerges from the flanks of the mound (designated 1JB). The remains of a third travertine area can be found at an apparently higher level between Jotun Spring Areas 1 and 2.

Several springs appear to evolve gas bubbles regularly. The composition of the gas has not been determined, although at 3A1 the smell of H_2S can clearly be distinguished.

The flow from the springs is impossible to assess as much of the run-off from the A-springs infiltrates directly into the permeable travertine as groundwater. It may be that only a minor proportion of the total spring flow is observed as surficial overflow from the springs.

Another thermal spring area has been reported by Otto Salvigsen, in a position between the Troll and Jotun springs, on the west of Bockfjord. Hitherto, it has not been documented in any detail.

5. SAMPLING PROGRAM

At almost all A-springs and a number of B-, C- and D-springs, pH, temperature and Eh were measured in the field (Appendix 4). At selected springs (seven A-springs at Troll, 2 D-springs at Troll, and Jotun springs 1JA3 and 2JB), field analyses of alkalinity were carried out and samples were collected for laboratory analysis. The selected A springs include the hottest springs of each spring area (except area 4). Additionally a cold spring between Spring Areas 3 and 4 at Troll was sampled (Sample K1). This is believed to be a permanent spring, as indicated by a verdant growth of spring moss, and is also believed to represent a discharge of non-thermal sub-permafrost groundwater (Type 2 - see above), an interpretation confirmed by the rather mature hydrochemistry of the water. A sample was also taken from a thaw seepage from the active layer between Spring Area 4 and 5 (Type 1, sample K2).

Field measurements of pH, temperature and Eh were made using a Yellow Springs YSI 3500 portable meter, calibrated regularly against buffer solutions of pH 4, 7 and 10. Alkalinity titrations were performed in the field using an Aquamerck kit with a pH=4.3 mixed indicator. An average of three separate titrations was taken.

On the first day 10 ml water samples for radon analysis were taken by injection into pre-filled vials containing a scintillation liquid (for method see Reimann et al. 1996). These were returned by helicopter to be analysed at the National Radiation Protection Authority within three days, using scintillation counting. Duplicate samples were taken, whose analysis indicated the very good reproducibility of the technique, even at low radon concentrations.

For each sampled spring 2 x 100 ml samples of filtered water were taken in 100 ml polyethylene bottles. These were rinsed thrice with spring water prior to sampling and twice with filtered spring water. Samples were filtered with 0.45 µm Millipore filters. On arrival at the Geological Survey of Norway (NGU) laboratory, one flask of each sample was acidified with 0.5 ml/100 ml concentrated Suprapure (Merck) HNO_3 to remobilize and preserve any precipitated or adsorbed metals. This sample was then analysed for 32 parameters at NGU by Inductively Coupled Plasma spectroscopy (ICP-AES - Ødegård and Andreassen 1987); Appendix 1. The second flask of each sample was sent to the Norwegian Agricultural University (NLH) for anion analysis by Ion Chromatography (IC): Appendix 2. The flask was then returned to NGU for confirmatory IC analysis: Appendix 1.

6. RESULTS

XRD analysis of travertine material from three spring areas (Troll springs, areas 1, 3 and 5) confirmed it to be composed of almost pure calcite (Appendix 6). No significant trace of either dolomite, aragonite or other major minerals was detected. The possible presence of minor amounts of monohydrocalcite, quartz and mica were indicated; the latter two could be detrital minerals.

The results of the water analyses are largely presented graphically in Figures 3-9 and in Tables 1 and 2. Ionic balances were found to be very good, all within 5 %. At the Jotun springs, alkalinity could not be determined in the field for logistical reasons. In the diagrams and calculations, alkalinity has been estimated from the ion balance.

Three groups of thermal waters can be distinguished purely on the basis of the ions Na, Ca, Mg, Cl^-, $SO_4^=$ and HCO_3^-.

(i) the southern Troll Spring Areas 1, 2 and 3 with Na-(Ca)-HCO_3^- composition

(ii) the northern Troll Spring Areas 5 and 6 with Na-HCO_3^- waters.
(iii) the Jotun springs with Na-Cl^- waters.

The waters within each group all have similar ionic composition in terms of proportions of major ions. Figure 3 shows pie diagrams of representatives of each water type, while Figure 4 plots the waters on a Durov diagram. The northern Troll springs are more similar to the southern Troll springs than the Jotun springs. It is also noteworthy that the sub-permafrost non-thermal spring K1 displays a Ca-(Na)-HCO_3^- composition which bears some resemblance to the southern Troll thermal waters. The thaw water K2 has a Ca-HCO_3^- composition reflecting the dominant lithology in the active layer - shattered marble fragments.

Figures 5-9 and Table 2 show the relationship between various parameters and temperature and will not be commented in detail, although the reader's attention is drawn to the following observations:

(i) pH and Eh tend to decrease with increasing temperature.
(ii) B, C and D springs generally exhibit lower temperatures and higher Eh values than A springs. Plots of Na vs. Cl^- (Fig. 8: and also Mg and Sr vs. Cl^-, not shown) indicate a limited degree of proportionate dilution from warmer (A) to colder (D) springs. A plot of Ca vs. Cl^- (Fig. 8) indicates, however, that calcium is being disproportionately attenuated to a much greater degree than chloride from the A to D springs.
(iii) alkalinities of all the thermal Troll springs are high (around 13 meq/l). The calculated alkalinities of the Jotun springs are somewhat lower, around 7-10 meq/l.
(iv) the Na, K, $SO_4^=$ and Si concentrations all show extremely good correlations with each other, and to a lesser extent with Cl^-. Concentrations of these parameters in all the Troll springs are similar, independent of temperature, although elevated relative to K1 and K2. 2JB contains higher concentrations of these parameters, 1JA3 the highest of all.
(v) the Na/Cl ratio in K2 is similar to that in sea-water (i.e. marine salts in precipitation). The other springs, including K1, exhibit significant non-marine excesses of Na.
(vi) Ca and, to a lesser extent Mg, show a better positive correlation with temperature than the parameters named in (iv)
(vii) Br/Cl mass ratios for the thermal waters range from 0.0018 in 1JA3 to 0.0029 in 2A4i. In sea-water, the ratio varies from 0.00325-0.0043 (Horne 1969, Michard et al. 1996), with a typical value of 0.00347 being used by Edmunds (1996).
(viii) Significantly elevated levels of Fe and Mn occur in the hotter A springs (this may be related to low Eh)
(ix) Rn levels are replicable and are significantly lower in the thermal springs than in K1
(x) All thermal waters exhibit reasonably consistent but elevated Na/Si (ca. 10) and Mg/Ca (ca. 0.3) mass ratios compared with K1 and K2 (Figure 9). The same applies to Sr/Ca (ca. 0.011) and Na/Ca (ca. 3) mass ratios (Table 2).

(xi) The thermal springs exhibit (Fig. 9) three groups of Na/K mass ratio; the Jotun springs at around 13.5 to 15.5, the southern Troll springs between 16 and 16.5 and the northern Troll springs at around 17.5. This grouping suggests that Na/K ratios may be a particularly interesting tool in the context of geothermometry.

7. INTERPRETATION

The thermal waters share some of the features exhibited by K1. This may imply either that some of the processes seen in the thermal waters can be explained by normal hydrochemical evolution occurring in the sub-permafrost zone, or that K1 includes a component of thermal water.

Observation (i) above suggests that 3A1 is the most 'original' of the Troll springs: it is the hottest, has the lowest Eh and the lowest pH and evolves large quantities of H_2S. The relationships of pH and Eh to temperature may suggest that the primary waters are of sub-neutral pH. The elevated pH at lower temperature may be related to degassing of CO_2. The primary waters may also be reducing, although it is also conceivable that reducing, H_2S-rich conditions are imposed during the water's slow percolation through biologically active sediments associated with the spring (although unless the biota refreshes itself, this process is likely to be self-limiting).

Observation (ii) suggests that the B, C and D springs represent re-emergences of the thermal waters after they have been subject to a limited degree of dilution by surficial waters and/or shallow groundwaters and lost heat to the air and to the travertine mass. The Ca vs. Cl^- plot suggests that calcium is being attenuated by other processes than dilution, probably by calcite precipitation. The fact that neither Mg nor Sr exhibit a similar degree of attenuation is compatible with the lack of dolomite or strontianite in the XRD spectrum.

Observations (iv), (x) and (xi) suggest that the waters may be partially derived from a deep-seated saline thermal water whose composition in terms of Na, K, Si and $SO_4^=$ is determined by a water-rock equilibrium. Michard et al. (1996) suggest that sodium concentrations can be taken as a good indicator of the extent of water-rock interaction in thermal waters of the crystalline basement of Switzerland. The lesser degree of correlation of these parameters with Cl^- and the variable, significant sodium-to-chloride excess (observation v), suggest that chloride is not wholly derived from water-rock interaction This hypothesis is supported by observation (vi): Nordstrom et al. (1989), Michard et al. (1996) and Edmunds (1996) regard an excess Br^-/Cl^- ratio as being indicative of chloride-derivation from "exotic" origins such as water-rock interaction (fluid inclusions, radiogenesis) or atmospheric pollution. The Br^-/Cl^-

ratios found in the Svalbard springs indicate a slight bromide deficit relative to sea-water. Such a deficit may indicate at least partial derivation of chloride salinity from halite evaporites or conceivably preferential adsorption of bromide on organic matter (Edmunds 1996). It is also conceivable that palaeo-seawater may have had a differing Br^-/Cl^- ratio to today.

Overall, the evidence suggests that the composition of the saline water body may result from a fossil sea-water modified by dilution, water-rock interaction, rather than purely from water-rock interaction. Another possibility is that the saline water may be derived from evaporite minerals. Evaporite deposits are not known on North Svalbard, but it cannot be excluded that they may exist at depth in the Devonian succession.

7.1 Geothermometry

At particular temperatures, common assemblages of minerals will tend towards equilibrium with a given water chemistry. Several researchers have noted that, for certain parameters or ratios of parameters, the relationship between temperature and composition will be stable and predictable. These parameters or ratios of parameters are known as geothermometers. In order for these to work, one has to assume that effects of dilution are insignificant and that thermodynamic equilibrium has been attained at reservoir temperature. In general, geothermometers based on ratios will be more resistant to dilution effects than those based on absolute concentrations. In addition, it should be realised that the temperature indicated by the geothermometer is not necessarily the maximum temperature of the water, but the temperature at which mineral and water phases were last in equilibrium with respect to the phases in question.

Several well-known geothermometers are summarised by Fournier (1981), who recommends three as being particularly appropriate to most low temperature thermal systems, namely the silica, the Na/K and the Na-Ca-K thermometers (Table 3). The simplest of these is the silica thermometer, which is simply based on the solubility of silica phases at differing temperatures. The geothermometer, being based on an absolute concentration, is susceptible to dilution and is also sensitive to assumptions made about the equilibrium silica phase (quartz or chalcedony, for example). In our case the quartz geothermometer yields temperatures of some 100 - 110°C for the Troll springs and up to 150°C for the Jotun springs.

Truesdell's (1976) Na/K geothermometer yields temperatures of 133 - 143°C for the Troll springs and around 150°C for the Jotun springs. Fournier's (1981) Na/K thermometer yields values between 30 and 40°C higher.

Finally, the more complex Na-K-Ca thermometer (Fournier & Truesdell 1973) indicates temperatures of around 60°C for both the Troll and Jotun springs, following correction for Mg content as indicated by Fournier & Potter (1979). The Na-K-Ca thermometer may, however, be susceptible to the effects of dilution if the proportion of "original" hot water in a mixture is 30% or less (which it may be in this case - see below). It is especially sensitive to possible errors if the uncorrected calculated temperature is around 100°C, where the $\beta = 1/3$ solution switches to the $\beta = 4/3$ solution (see Fournier 1981). The Na-K-Ca thermometer may also not be applicable in the Bockfjord case as Na and K concentrations are likely to be controlled by a feldspar equilibrium at depth in silicate-dominated Hecla Hoek or older rocks. It is possible that the Ca-Mg signature is picked up at a shallower depth and lower temperature during the water's transit through carbonate-rich rocks of the upper Hecla Hoek. The Na-K-Ca thermometer is therefore of dubious applicability in this study.

The degree of dilution can be accounted for by the method of Fournier and Truesdell (1974). In essence this involves the solution of two simultaneous equations to find the factor X (the proportion of diluting cold water), and the original temperature of the hot saline water T:

$X = (Si_T - Si_{spr})/(Si_T - Si_{cold})$
$X = (H_T - H_{spr})/(H_T - H_{cold})$

where Si_T, Si_{spr}, Si_{cold} are concentrations of silicon in the original saline water at temperature T, in the sampled spring and in the cold dilution water respectively. H_T, H_{spr} and H_{cold} are the enthalpies of the same waters. In all cases, K1, the supposed sub-permafrost groundwater, is taken as the cold diluting water. As Si_T is a direct function of temperature (the solubility of a silica phase such as quartz), as is H_T, the equations may be solved. By plotting X for a range of T, the intersection of the two lines gives the solution of the equations. In fact, a third equation can be added to further constrain the result. We can write similar equations for Na and K:

$X = (Na_T - Na_{spr})/(Na_T - Na_{cold})$
$X = (K_T - K_{spr})/(K_T - K_{cold})$
also: $Na_T/K_T = R_T$

where R is a ratio depending on temperature T, according to, for example, relationships derived by Truesdell (1976) or Fournier (1981).
Thus:
$X = (Na_{spr} - R_T.K_{spr})/(Na_{cold} - R_T.K_{cold})$
In fact, the solution to this system of equations is very insensitive to dilution X and gives a value of T similar to that initially derived from the Na/K geothermometers.

The triangle defined by the lines for Na/K, Si and H on Figure 10a define a likely area for the original geothermal water based on information from spring 3A1. Fournier & Truesdell (1974) note that in many systems, the H curve will overestimate T as it assumes no heat loss due to steam loss or factors other than dilution. Thus, the intersection of the Na/K and Si curves is a promising indicator of T and X. In the case of spring 3A1 and Fournier's (1981) geothermometer for Na/K, a temperature of some 180°C with a ratio of some 80%:20% cold:hot water is indicated. Truesdell's (1976) geothermometer results in a larger X:T triangular window, but a temperature of 140°C and X of less than 0.6 are a possibility. Similar results (for Si and enthalpy) can be obtained by using the plot in Fig. 4.10 of Fournier (1981), reproduced here as Figure 12.

The technique is applied to waters 5A3 and 1JA3 in figures 10b and 10c. The possible X:T windows are larger than for 3A1 but yield not dissimilar results. 1JA3 suggests somewhat higher minimum temperatures than the waters from the Troll springs. This is not surprising as the Jotun springs lie a considerable distance from the Troll springs and probably represent a different hydrothermal system. They are also nearer to Sverrefjell volcano.

In summary, the most plausible geothermometric techniques suggest that the Troll thermal springs are derived from a hot saline water of original temperature between 130 and 180°C, probably diluted by between 70 and 90% by cold, sub-permafrost groundwater of the type observed in K1 during its passage to the surface. Given an average geothermal gradient of 0.079°C/m, the geothermometer temperatures correspond to a depth of some 1.6 - 2.3 km.

7.2 Critique of Geothermometry

The use of geothermometers, especially for high CO_2, cool springs, is fraught with difficulties:

(i) the Na-Ca-K thermometer, with magnesium correction, is susceptible to interference by high-level dissolution of Mg and Ca by cool, aggressive, high-CO_2 water from readily soluble carbonates of the Hecla Hoek Marbles.

(ii) the Na-K thermometer may also be susceptible to interference from the same source (i.e. dissolution of Na and K from high-level marbles). In defence of the thermometer, the concentrations of Na and K in the marbles are very low (particularly in Sv5R - see Table 4), but the ratio Na/K is much lower in the marbles than the water. A Na/K fingerprint from the marbles on the waters would thus tend to artificially lower the aqueous Na/K ratio, resulting in misleadingly high calculated temperatures.

(iii) it may thus be suggested that the waters do not contain a high-temperature component at all, but reflect waters circulating at shallow depths with little dilution. Nevertheless, dissolved silicon concentrations (using the chalcedony thermometer, which may be more appropriate for low T waters) suggest minimum equilibration temperatures of at least 70°C for the Troll springs and 90-130°C for the Jotun springs, even without taking into account possible dilution.

(iv) even the chalcedony geothermometer is open to question, however, in cool, aggressive waters which are rich in CO_2. Such waters may attack silicate minerals other than silica. Silicon concentrations may then accumulate in the water in concentrations greater than that reflecting quartz/chalcedony saturation (due to the slow kinetics of silica precipitation). Use of silica geothermometers in such situations will thus overestimate temperatures.

7.3 Speciation and Saturation Modelling

The composition of the sampled spring waters was modelled using the code MINTEQA2. Iron and manganese redox couples were activated. Selected results of the modelling are indicated in Figures 11a-c. In the following discussion, the term 'saturation' is used to apply to waters within ± 0.3 of a saturation index (SI) of zero. The following features can be noted:

(i) The thaw water K2 is saturated with respect to calcite and quartz, but significantly undersaturated with respect to dolomite, magnesite, strontianite, microcline, albite, anorthite, fluorite and barite. It is supersaturated with respect to goethite, kaolinite and montmorillonite. It is a typical shallow groundwater from a calcitic rock, where normal subaerial carbonate and silicate weathering processes are occurring.

(ii) The cold sub-permafrost groundwater K1 is saturated with respect to chalcedony, but supersaturated with respect to quartz, kaolinite, montmorillonite and goethite. The water is undersaturated with respect to calcite, dolomite, magnesite, strontianite, fluorite, barite, and the feldspar phases. The quartz oversaturation and calcite undersaturation are slightly unusual; the former may possibly be ascribed to mixing with a deeper, thermal water.

(iii) The hottest thermal water 3A1 is approximately saturated with respect to a number of mineral phases including kaolinite, microcline, aragonite, barite, calcite, dolomite. It is supersaturated with respect to fluorite, chalcedony and quartz and undersaturated with respect to the feldspar phases, magnesite and strontianite. These observations confirm that 3A1 is in approximate carbonate equilibrium with respect to dolomite and calcite (comprising the bulk of the surrounding dolomitic marble bedrock). The supersaturation with respect to the silica phases confirms that the precipitation of silica is kinetically slow relative to the implied rapid ascent of the thermal waters. The other hot (> c. 20°C) waters exhibit similar saturation features to 3A1.

(iv) The cooler thermal waters, which have presumably been subject to more dilution during their upward ascent or (in the case of the 'D' springs) through the secondary travertine tend towards a greater degree of supersaturation with respect to the carbonate and silicate minerals. The waters between 10 and 15°C tend to exhibit calcite, aragonite and dolomite supersaturation and in two cases approximate magnesite saturation. These minerals are thus all candidates for possible deposition in travertine. XRD spectra indicate however that calcite is the unique detectable carbonate constituent in travertine samples. The cooler waters also tend to become supersaturated with respect to microcline and albite. The increasing saturation with respect to carbonate minerals can be ascribed to progressive degassing of carbon dioxide as water nears the surface environment, this leads to an increase in pH affecting the saturation of carbonate phases. Phases such as quartz, chalcedony, fluorite and barite show little change in saturation status relative to the hot waters, the solubility of these minerals not being directly pH dependent.

(v) The minerals gypsum, rhodochrosite, strontianite and siderite are undersaturated in all samples. The lack of strontianite saturation suggests that strontium is a mobile element and a useful indicator of water-rock interaction and dilution.

8. CONCLUSION

The Bockfjord thermal spring waters can be divided into three groups of similar ionic composition. Troll spring areas 1-3 yield waters of Na-(Ca)-HCO_3^- composition, areas 5 and 6 waters of Na-HCO_3^- composition and the Jotun springs waters of Na-Cl^- composition. There is a negative correlation between temperature and Eh and temperature and pH. The warmest water, at 25.6°C, has an Eh of -270 mV, a pH of 6.83 and contains hydrogen sulphide. It is thus suggested that the "pristine" thermal water source has a sub-neutral pH and may be reducing (although the low Eh may alternatively result from biological activity in near-surface sediments). The thermal waters are also likely to be CO_2-bearing; although no gas samples were taken, the negative relationship of pH and temperature is indicative of degassing of CO_2.

Common geothermometers yield widely varying temperatures for the thermal water source. A combination of Na/K, silica and enthalpy calculations suggests temperatures at depth of 130 - 180°C for the Troll springs, with 10-30% thermal water diluted by 70-90% cold water, although these techniques are open to criticism. These temperatures correspond to depths of 1.6 - 2.3 km. If no dissolution is assumed, the chalcedony geothermometer alone indicates temperatures of around 70°C. The Jotun springs appear to be derived from a thermal water source some few tens of °C hotter. However, each geothermometer is open to serious criticism in cool, high pCO_2 waters and the real circulation depth and temperature could be significantly lower. Drilling would be required to unambiguously evaluate water temperatures at depth.

Br^-/Cl^- ratios suggest that the water's chloride salinity is not derived from water-rock interaction but rather from fossil sea-water or, conceivably, evaporitic deposits in the Devonian sandstones. The sodium, potassium, sulphate and silicon concentrations appear to be controlled by near-equilibrium water-rock interactions at depth.

9. ACKNOWLEDGEMENTS

Field work at Bockfjord was funded by a grant from the Research Council of Norway to the Agricultural University of Norway. The Norwegian Polar Institute was responsible for the logistics of the expedition to Bockfjord. ICP-MS analyses of Al (see Fig. 11) were provided by Dr. Ulrich Siewers of the Federal Institute for Geosciences and Natural Resources (BGR), Hannover, Germany. Radon analyses were kindly carried out by Prof. Terje Strand and colleagues at the Norwegian Radiation Protection Authority. We would like to thank the Governor of Svalbard for granting permission for our work in the National Park of Northern Spitsbergen.

10. ABBREVIATIONS USED

mg/l = milligrams per litre
Bq/l = becquerels per litre
meq/l = milliequivalents per litre
µS/cm = microsiemens per centimetre
km = kilometres
µm = micrometres
°C = degrees Centigrade
mV = millivolts
$mW.m^{-2}$ = milliwatts per square metre

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Table 1. Composition of Troll and Jotun springs, Bockfjord, according to Hoel & Holtedahl (1911)

	Troll springs No. 3	**Jotun Spring No.1**	**Jotun Spring No.2**
Total mineral content (mg/l)	988	2410	1456
Non-volatile mineral content (mg/l)	780	2178	1256
$SO_4^{=}$ (mg/l)	36	104	61
Cl^{-} (mg/l)	122	779	419
Ca (mg/l)	109	114	100
Mg (mg/l)	41	34	28

Table 2. The chemical composition of the sampled springs.

All units are in mg/l unless otherwise stated. Values in rounded parentheses represent values calculated from the ionic balance.

For radon determinations, a detection limit of 10 Bq/l is cited, although actual duplicate determinations (shown in square parentheses) indicate that this limit is probably too high.

Spring	*T (C)*	*Alkalinity (meq/l)*	*Eh (mV)*	*pH*	*EC (µS/cm)*	*Rn (Bq/l) duplicates*	*F^-*	*Cl^-*	*Br^-*	*NO_3^-*	*$SO_4^=$*	*Si*	*Mg*	*Ca*	*Na*	*K*	*Fe*	*Mn*	*Ba*	*Sr*	*B*	*Li*
1A5	21.6	13.2	-220	6.80	16070		3.35	147	0.408	<0.05	52.9	23.8	33.5	111	214	13.1	0.031	0.011	0.112	1.1	0.226	0.350
2A4i	22.5	13.2	-240	6.68	14960		3.32	144	0.412	<0.05	49.2	23.4	33.0	111	212	13.0	0.025	0.014	0.113	1.1	0.228	0.350
2A4ii	13.4	13.2	-60	7.19	15810	<10 [2]	3.29	147	0.413	<0.05	49.5	21.7	33.0	104	211	13.1	0.029	0.013	0.107	1.1	0.218	0.346
3A1	25.6	13.1	-273	6.83	16300	<10 [9, 8]	3.26	150	0.386	<0.05	50.7	23.5	33.1	110	212	13.2	0.093	0.014	0.112	1.1	0.212	0.348
3Di	9.5	11.3	216	7.65	14080		3.21	135	0.365	0.18	46.4	21.4	29.7	81.3	200	12.7	<0.01	<0.001	0.097	0.96	0.210	0.324
5A3	19.4	13.5	133	6.78	19420	<10 [7, 7]	3.93	228	0.631	0.21	55.3	29.3	29.2	99.0	288	16.6	<0.01	0.017	0.105	1.1	0.331	0.456
5A4	14.5	13.6	159	7.47	18380		3.87	221	0.534	0.23	57.2	28.6	31.1	88.6	282	16.3	0.010	<0.001	0.096	1.1	0.325	0.454
5Dii	11.8	12.9	160	7.18	18300		3.92	216	0.552	0.18	56.0	28.9	29.1	84.2	276	16.2	<0.01	<0.001	0.096	1.0	0.323	0.438
6A1	20.0	13.7	70	6.69	19140		3.97	220	0.581	<0.05	56.6	28.3	28.4	94.8	283	16.0	0.063	0.013	0.110	1.1	0.311	0.443
1JA3	23.0	(10.4)	-100	6.67			4.56	958	1.73	<0.05	108	60.7	29.3	112	706	46.5	0.183	0.011	0.099	1.4	1.06	1.17
2JB	13.8	(7.3)	200	7.08			3.19	495	1.02	0.15	73.8	32.0	25.2	96.4	354	25.9	<0.01	<0.001	0.053	0.94	0.601	0.643
K1	3.6	5.4	203	7.00	16120	65, 69	0.92	29.1	<0.1	0.23	15.8	6.5	12.3	68.8	46.7	3.7	<0.01	<0.001	0.037	0.32	0.045	0.071
K2	0.2	2.2	230	7.97	2420		0.10	4.76	<0.1	<0.05	7.16	0.70	4.1	41.4	2.4	<0.5	<0.01	<0.001	0.008	0.051	<0.01	<0.005

Table 3. Calculated temperatures (°C) by the application of common geothermometers to the sampled waters. The geothermometers used are those summarised by Fournier (1981). For the Na-K-Ca thermometer, the ß=1/3 value is used (bold type) if the ß=4/3 value is > 100°C.

Spring	*T (C)*	*Na/K - Fournier (1981)*	*Na/K - Truesdell (1976)*	*Quartz - no steam loss*	*Chalcedony*	*Na-K-Ca (ß=4.3) Fournier & Truesdell (1973)*	*Na-K-Ca (ß=1.3) Fournier & Truesdell (1973)*	*T corr for Mg content Fournier & Potter (1979)*	*Na-K-Ca (corr.) Fournier & Potter (1979)*
1A5	21.6	178	140	103	73	**78**	145	14	64
2A4i	22.5	178	140	102	72	**78**	145	13	65
2A4ii	13.4	179	141	98	68	**80**	146	18	62
3A1	25.6	179	141	102	72	**79**	146	14	64
3Di	9.5	181	143	98	67	**83**	149	29	55
5A3	19.4	174	135	113	84	**92**	148	31	61
5A4	14.5	174	135	111	82	**94**	149	41	53
5Dii	11.8	175	137	112	83	**95**	150	41	54
6A1	20.0	172	133	111	82	**92**	147	31	61
1JA3	23.0	184	147	152	127	142	**168**	104	64
2JB	13.8	192	156	117	88	112	**163**	103	60

Table 4. X-Ray Fluorescence (XRF) analytical results for Mg, Ca, Na and Ca (as oxide %) for selected rock samples, and calculated molar and mass ratios. Analyses performed by Ulrich Siewers at the Federal Institute for Geosciences and Natural Resources (BGR), Hannover, Germany. See appendix 5.

Sample No.	*Rock type*	*MgO*	*CaO*	*Na_2O*	*K_2O*	*Mg/Ca*	*Na/K*	*Mg/Ca*	*Na/K*
		%	%	%	%	molar	molar	mass	mass
Sv1R	Fine grained grey Hecla Hoek marble. Troll.	0.74	52.41	0.13	0.26	0.020	0.76	0.012	0.45
Sv5R	Fine grained buff Hecla Hoek marble. Troll.	17.99	29.27	0.01	0.01	0.855	1.52	0.519	0.89
Sv17R	Coarser Hecla Hoek marble. Jotun.	0.75	52.62	0.29	0.07	0.020	6.29	0.012	3.70
Sv19R	Mica schist. Hecla Hoek. Jotun.	2.13	1.79	2.37	4.71	1.655	0.76	1.004	0.45
Sv28R	Devonian Old Red Sandstone. Troll.	0.87	2.05	0.34	1.51	0.590	0.34	0.358	0.20
Sv3R	Recent travertine - Troll area 5A4	0.84	50.91	0.11	0.03	0.023	5.57	0.014	3.28
Sv10R	Fossil travertine Troll area 1	1.13	51.77	0.13	0.1	0.030	1.98	0.018	1.16
Sv11Ra	Fossil travertine Troll area 3	0.67	54.23	0.09	0.01	0.017	13.67	0.010	8.04
Sv11Rb	Fossil travertine Troll area 3	1.01	53.79	0.1	<0.01	0.026	>15.2	0.016	>8.9
Sv14R	Fossil travertine - Troll area 7	0.77	53.43	0.05	0.05	0.020	1.52	0.012	0.89
Sv15R	Recent travertine - Troll area 3A2	0.55	52.58	0.2	0.02	0.015	15.19	0.009	8.94

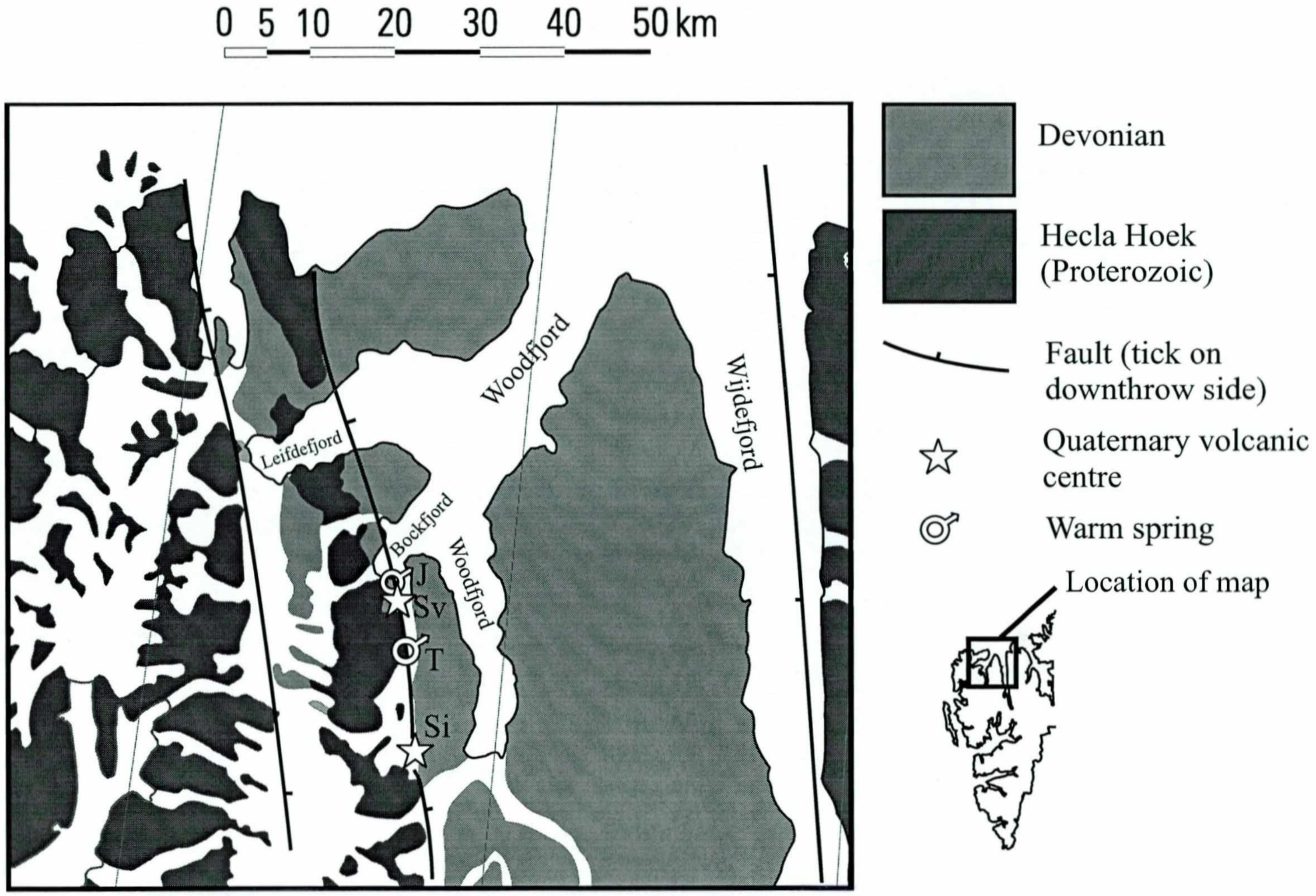


Figure 1. Sketch map of the Woodfjord area of Northern Svalbard. J = Jotun springs, Sv = Sverrefjellet, T = Troll springs, Si = Sigurdfjellet. The white areas represent glacier covered terrain or terrain covered by Quaternary (moraine / sandur) deposits. Inset shows map of Spitsbergen with location of main map.

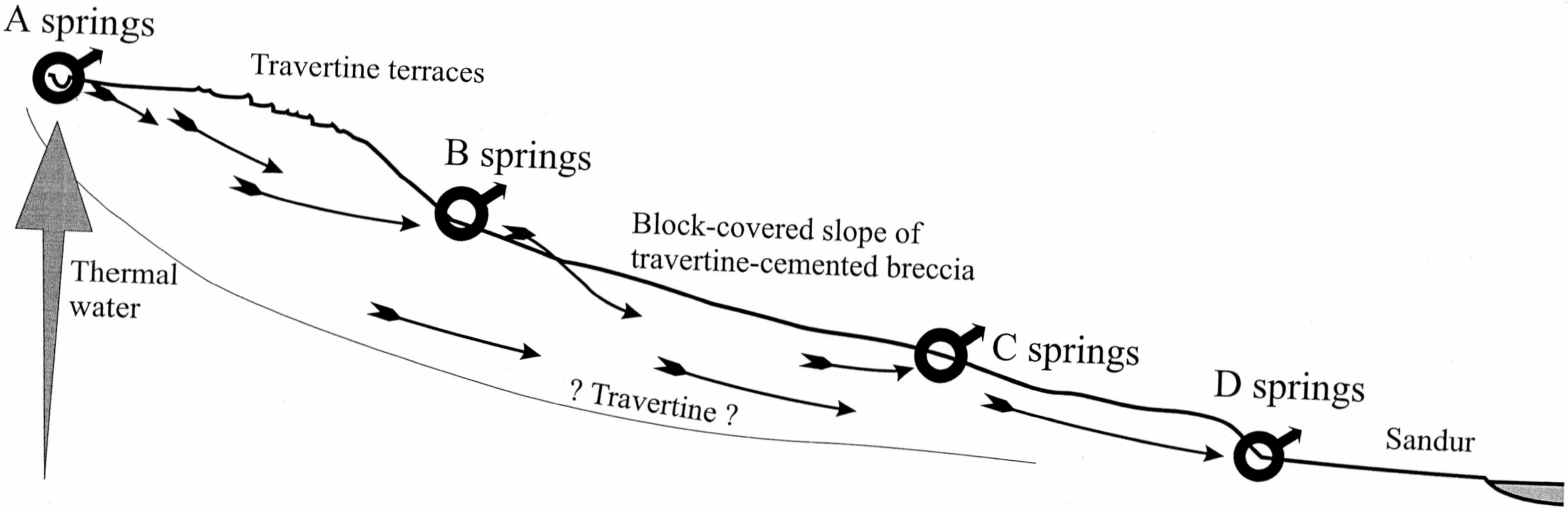
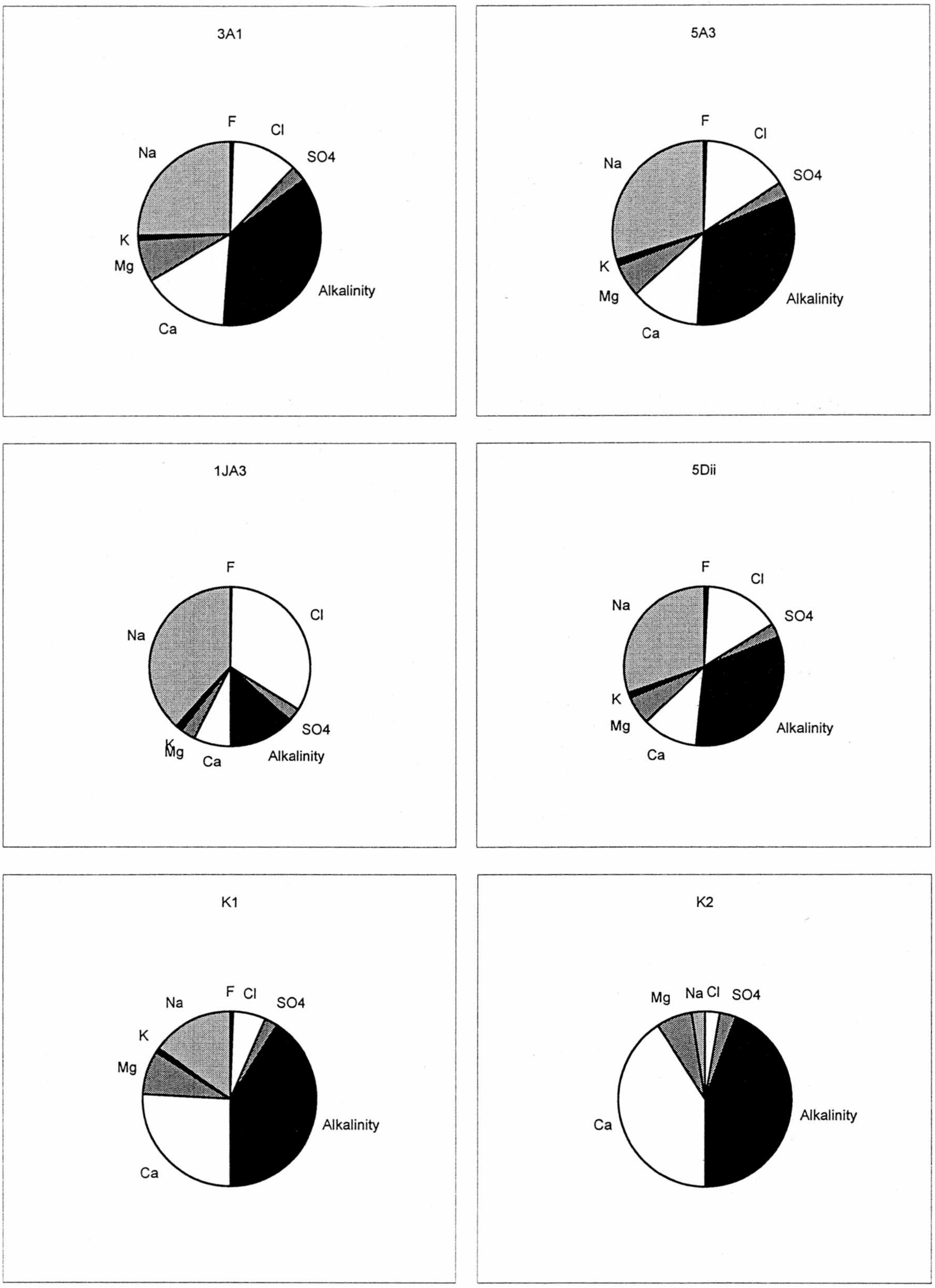


Figure 2. Schematic cross-section of the structure and probable groundwater flow at the Troll Springs site, Svalbard.

Figure 3. Pie diagrams showing major ion composition of groundwaters from springs 3A1, 5A3, 5Dii, 1JA3, K1 and K2.



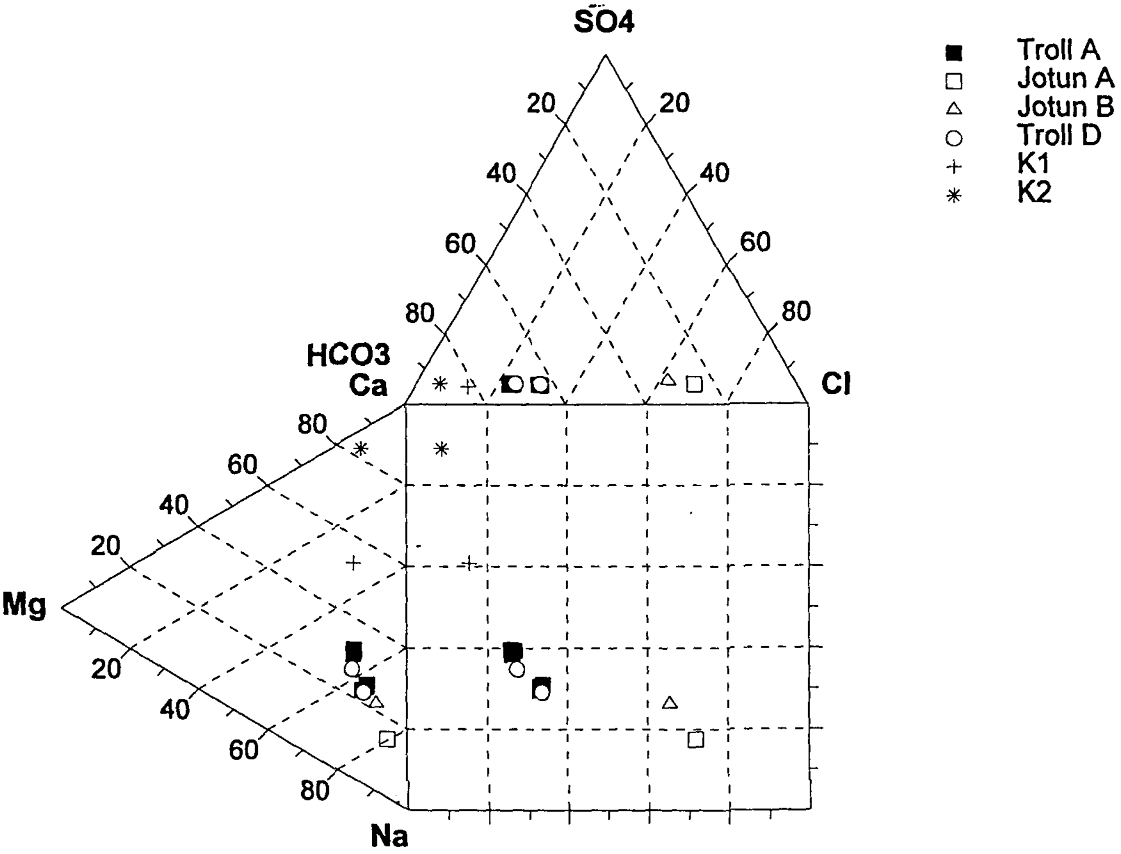


Figure 4. Durov diagram showing the major-ion composition of groundwaters (based on meq/l) from the Troll and Jotun spring areas.

Figure 5. Plots showing the relationship of temperature to Eh and pH, Bockfjord springs, Svalbard. In the box-plots of the lower two diagrams, the "box" represents the interquartile range, with the median shown by a horizontal line. The whiskers represent the extraquartile data. Box-plots are not calculable for samples of less than 5: in such cases the data points are shown as lines.

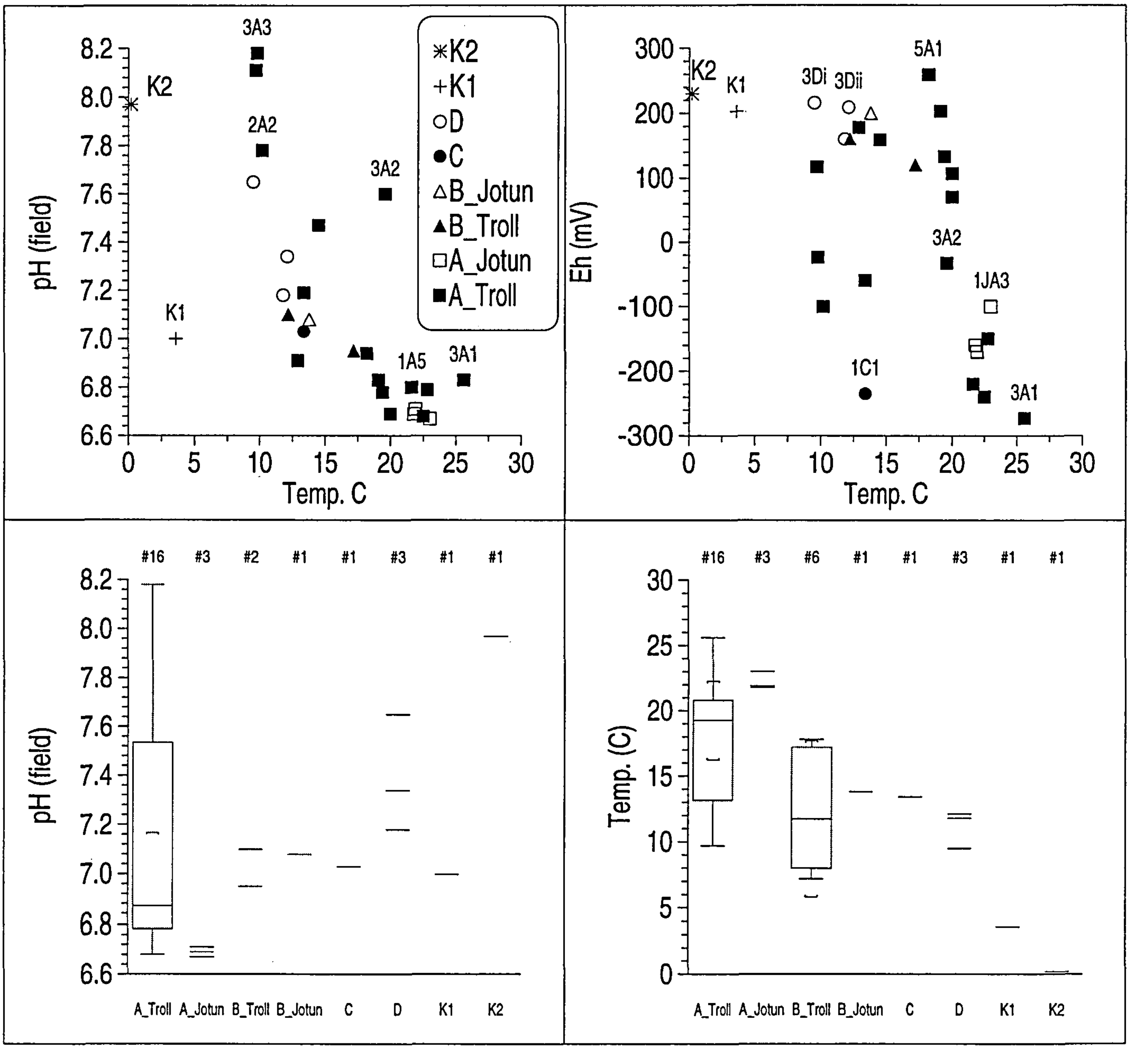


Figure 6. Plots showing the relationship of selected parameters to temperature. In cases where the parameter is below the analytical detection limit, a value of half the detection limit is plotted.

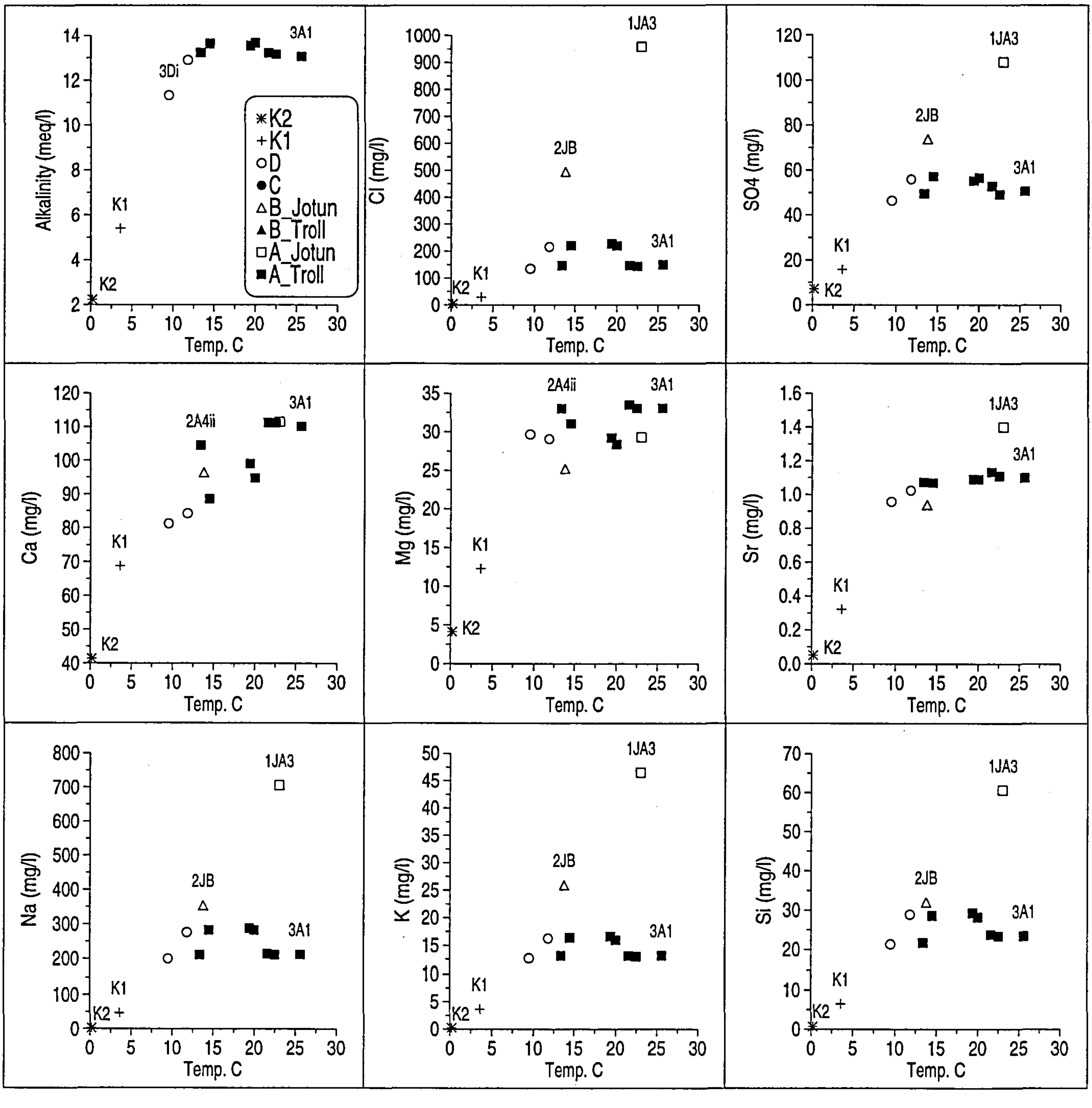


Figure 7. Plots showing the relationship of selected parameters (F^-, Fe, Mn and Rn) to temperature. In cases where the parameter is below the analytical detection limit, a value of half the detection limit is plotted.

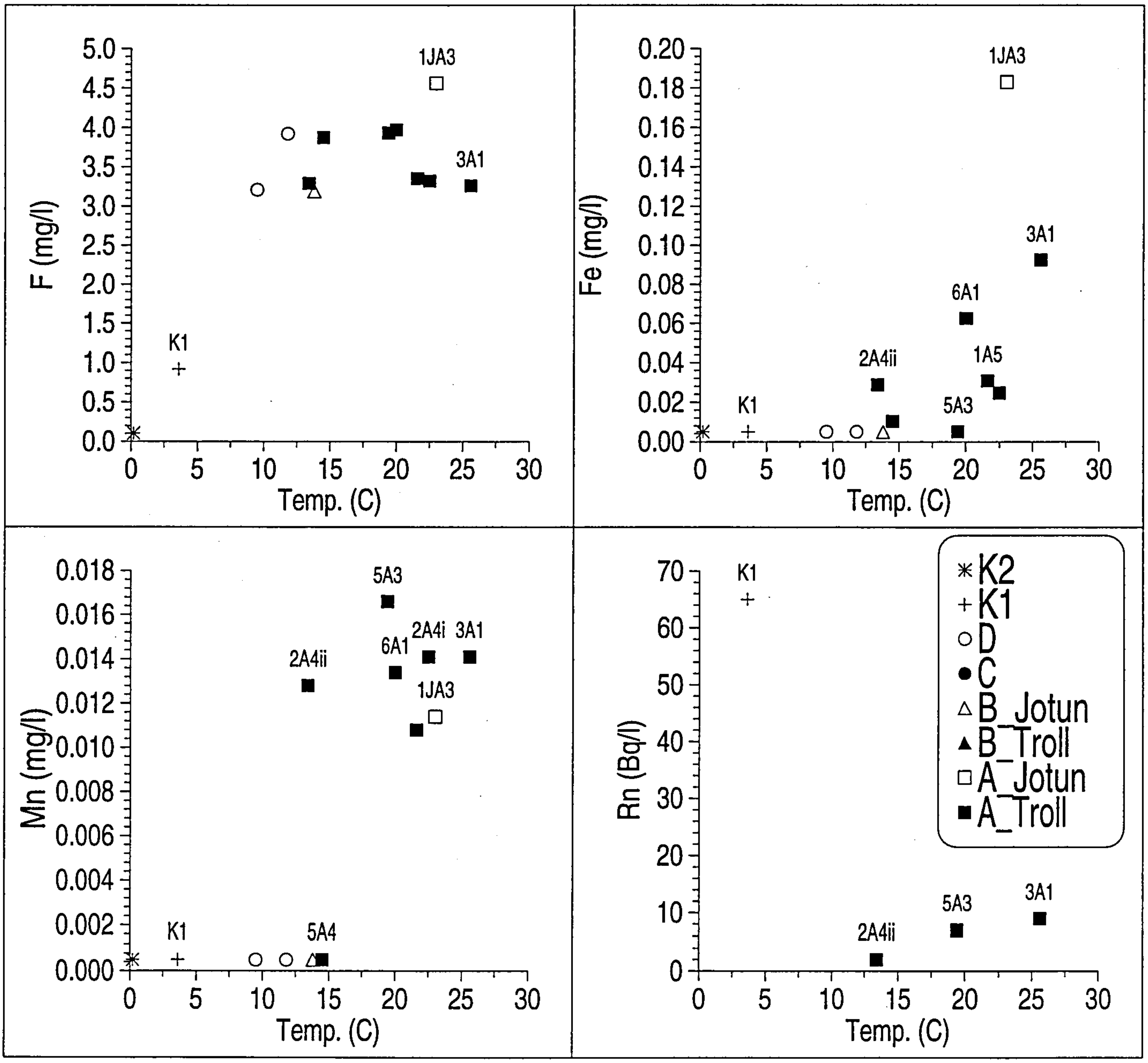


Figure 8. Plots showing the inter-relationship of selected major ions (Na, Ca, K, Cl^- and SO_4^{2-}). In cases where the parameter is below the analytical detection limit, a value of half the detection limit is plotted.

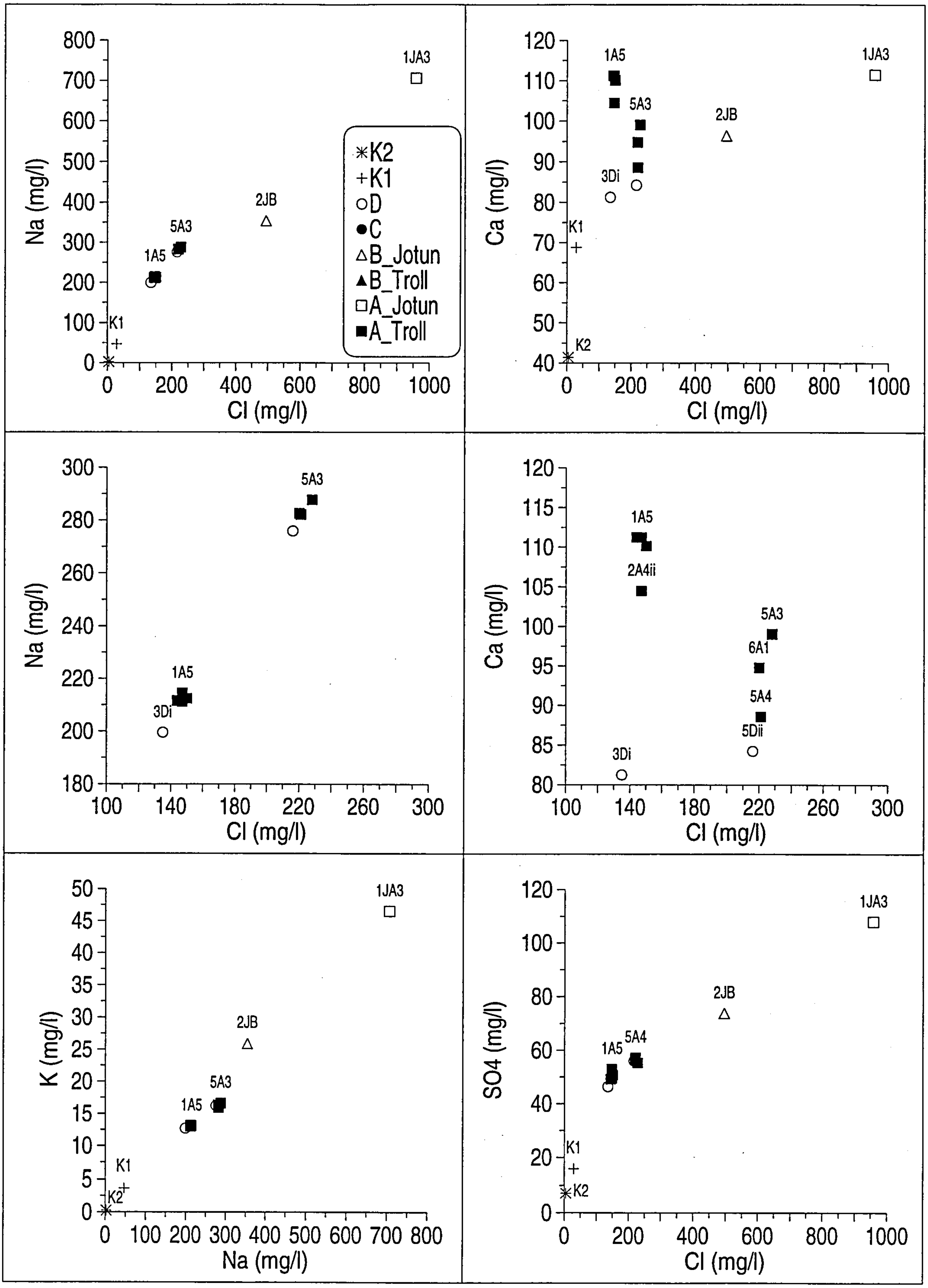
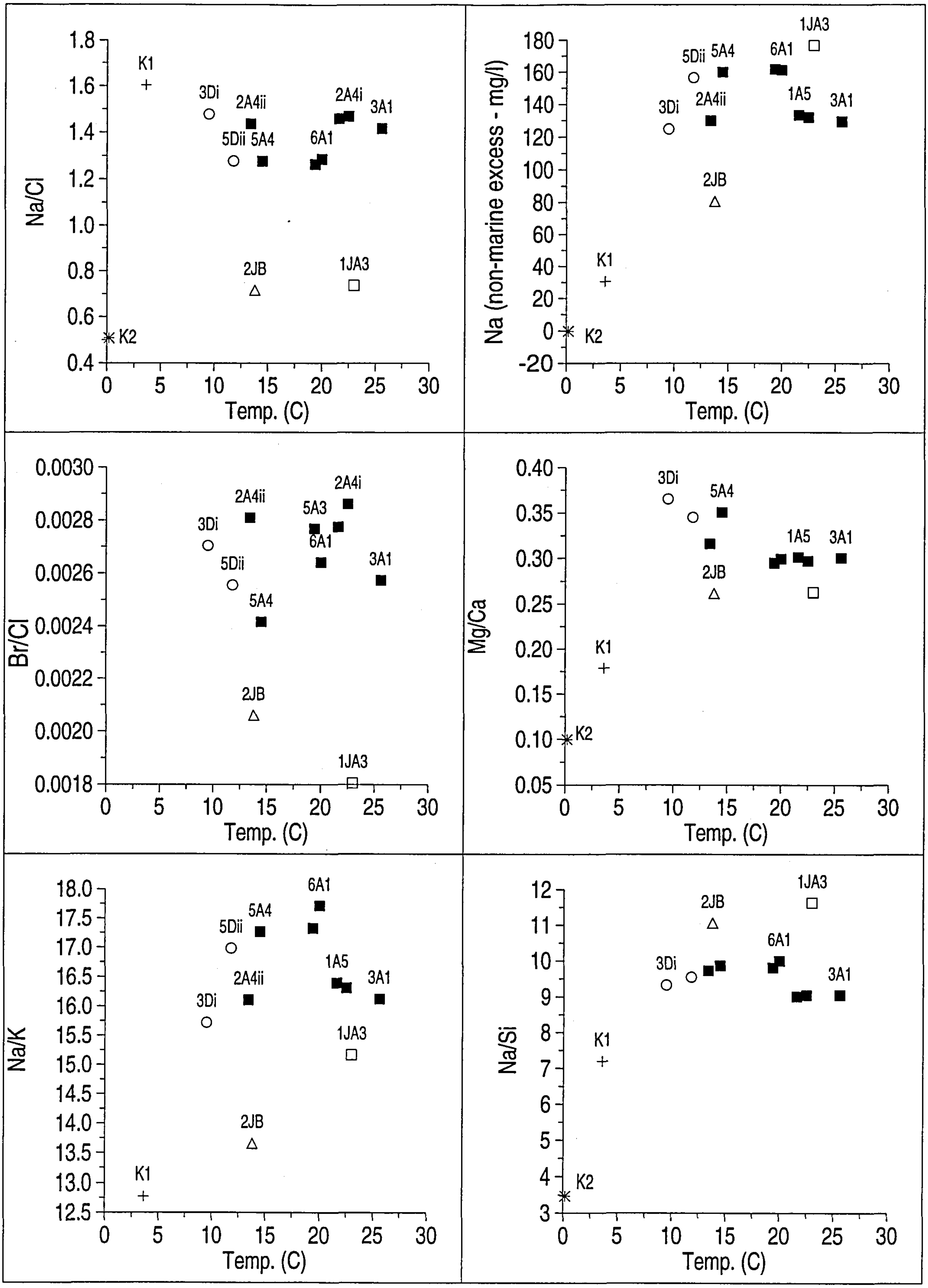
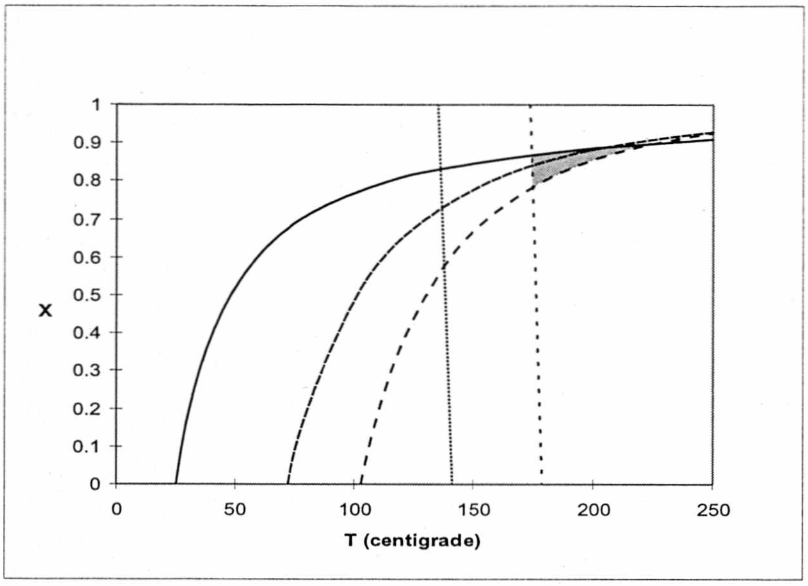
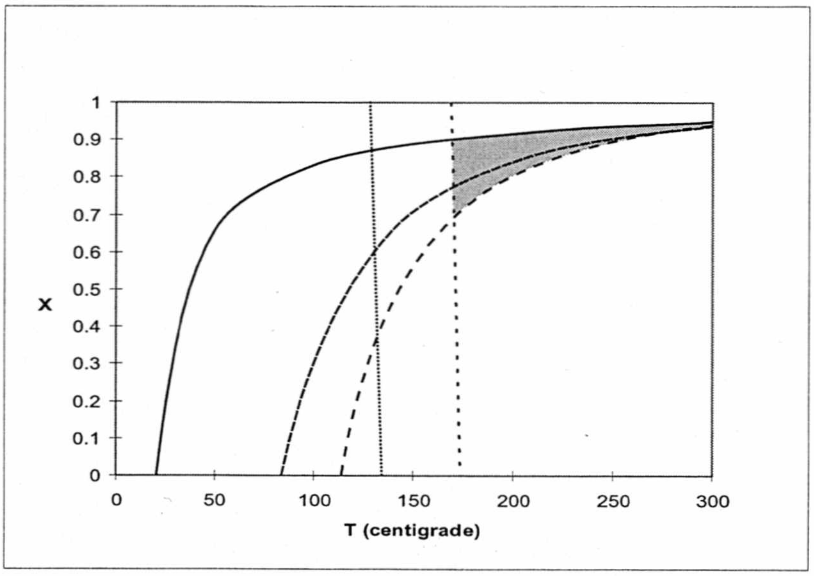


Figure 9. Plots showing the relationship of selected mass ratios and non-marine sodium excess (Na*) to temperature. In cases where one parameter of the ratio is below the analytical detection limit, no point is plotted.

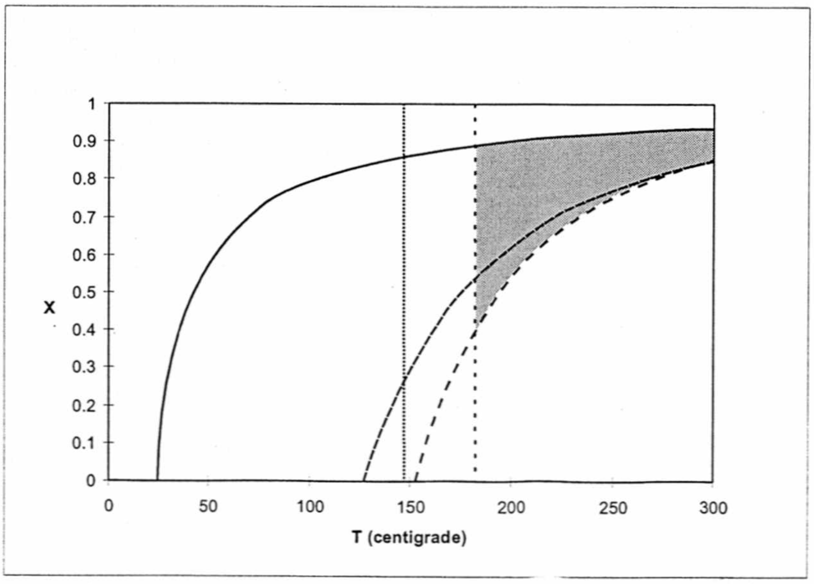




3A1



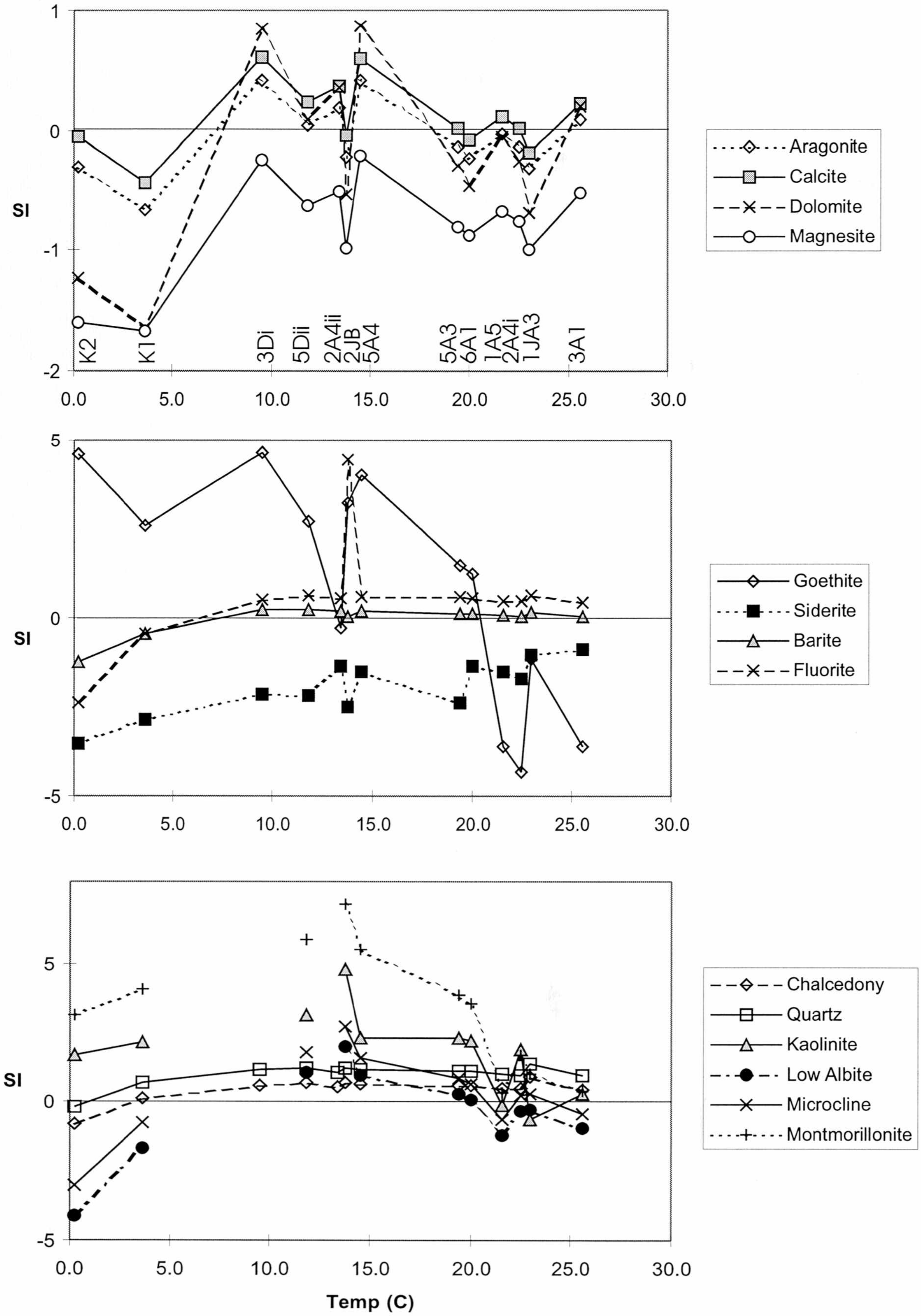
5A3



1JA3

Figure 10. Mixing curves plotted for X (proportion of cold water) vs. temperature T, using quartz solubility, chalcedony solubility, enthalpy and the Na/K thermometers of Fournier (1981) and Truesdell (1976). The shaded area represents the area enclosed by Fournier's (1981) Na/K thermometer, quartz solubility and the enthalpy dilution line.

Figure 11. Plots showing the relationship of various saturation indices to temperature. In the few cases where a parameter is below the analytical detection limit, a value of half the detection limit has been used as input to MINTEQA2. In several samples where Al is below detection limit for ICP-AES, values derived from ICP-MS analyses carried out at BGR, Hannover, were used.



Produced from svalalk.xls on 24.10.97 from spreadsheet SI after correction of Na/Alk values

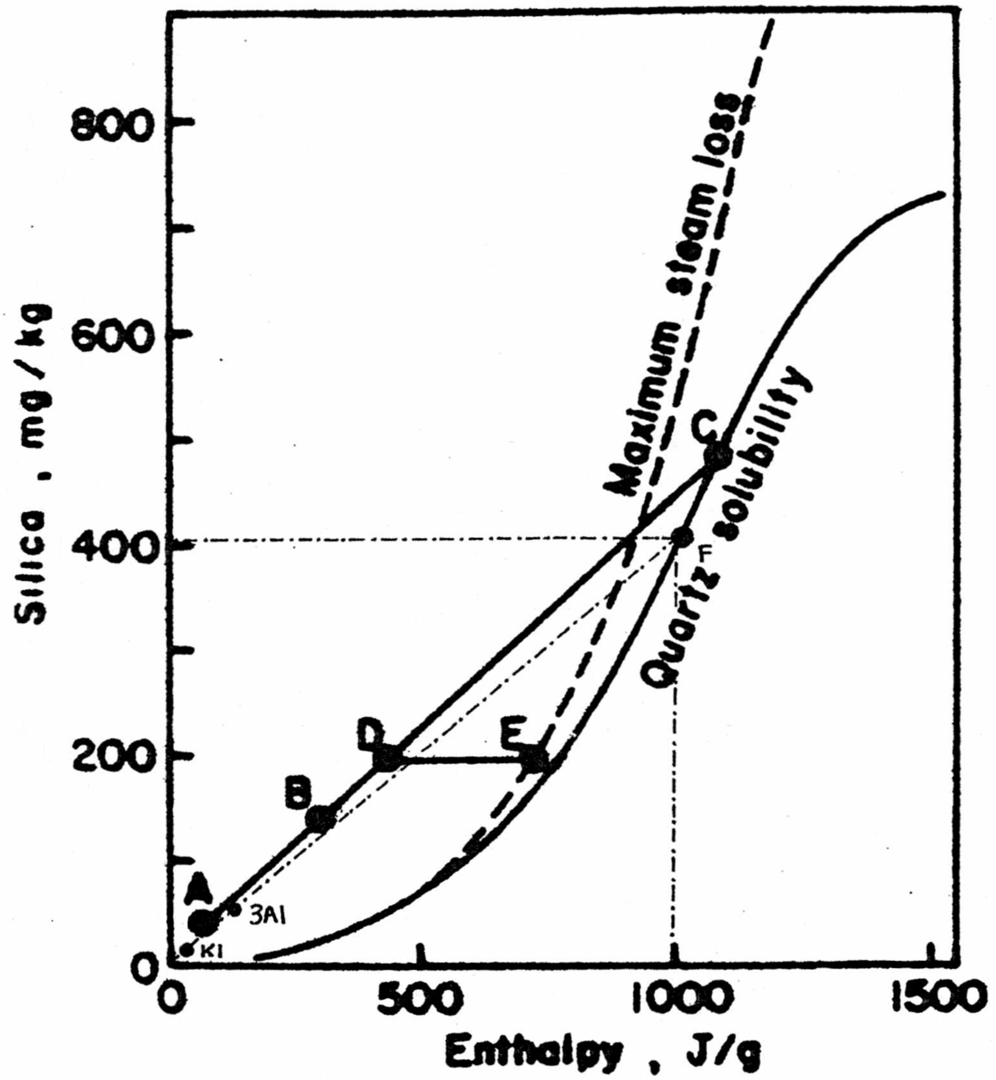


Figure 12. Estimation of temperature of 'original'thermal water using Fournier's (1981) silica-enthalpy diagram. A line drawn through K1 (Si = 6.5 mg/l, T = 3.6 °C; i.e. SiO_2 = 13.9 mg/l, H = 15.1 J/g) and 3A1 (Si = 23.5 mg/l, T = 25.6 °C; i.e. SiO_2 = 50.3 mg/l, H = 107.2 J/g), intersects the quartz solubility curve at point F; i.e.H = 1000 J/g (T=232°C) and SiO_2 = 403 mg/l (Si = 188 mg/l). The latter implies a dilution factor (proportion of cold water) of around 0.9. This is similar to the results obtained for SiO_2 and enthalpy in Figure 10. The results for Svalbard are shown as a dotted line.

Appendix 1

Analytical Results from NGU

Ion chromatography (filtered [0.45μm], unacidified water samples)
ICP-AES (filtered [0.45μm], acidified water samples)

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ANALYSERAPPORT

NORSK
AKKREDITERING
Nr. P020

ANALYSEKONTRAKT NR.: 1996.0121
NGU PROSJEKT NR.: 2717.00

OPPDRAGSGIVER: NGU, Varme kilder Svalbard

ADRESSE:

TLF.: 310

KONTAKTPERSON: David Banks

PRØVETYPE: Vann
ANTALL PRØVER: 12
IDENTIFIKASJON AV PRØVER: Iflg. liste fra oppdragsgiver
PRØVER MOTTATT: 30.07.96
ANMERKNINGER: Ingen

SPESIFIKASJON AV OPPDRAGET I HENHOLD TIL ANALYSEKONTRAKT:

METODE	DOKUMENTASJON *)	OMFATTES AV AKKREDITERING
ICP-AES vann	NGU-SD 3.1	Ja
IC	NGU-SD 3.4	Ja

Denne rapporten inneholder i alt 7 sider. Rapporten må ikke gjengis i utdrag uten skriftlig godkjenning fra NGU-Lab.

Alle forhold ved prøvetaking, behandling og transport av prøvene før innlevering til NGU-Lab er underlagt oppdragsgivers ansvar. Analyseresultater framlagt i denne rapporten refererer derfor kun til det prøvematerialet som er mottatt av NGU-Lab.

Trondheim, 28. august 1996

Magne Ødegård (e.f.)

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*) Fortegnelse over dokumentasjon finnes i NGU-Labs Kvalitetshåndbok, NGU-SD 0.1, som kan rekvireres fra NGU-Labs sekretariat.

NGU
Norges geologiske undersøkelse

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ICP-AES ANALYSER
VANN
Analysekontraktsnr:1996.0121

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Nr. P020

INSTRUMENT TYPE : **Thermo Jarrell Ash ICP 61**

NEDRE BESTEMMELSESGRENSER VANNANALYSER

(For vannprøver som tynnes, blir deteksjonsgrensene automatisk omregnet).

Si ppb	Al ppb	Fe ppb	Ti ppb	Mg ppb	Ca ppb	Na ppb	K ppb	Mn ppb	P ppb
20.-	20.-	10.-	5.-	50.-	20.-	50.-	500.-	1.-	100.-
Cu ppb	Zn ppb	Pb ppb	Ni ppb	Co ppb	V ppb	Mo ppb	Cd ppb	Cr ppb	Ba ppb
5.-	2.-	50.-	20.-	10.-	5.-	10.-	5.-	10.-	2.-
Sr ppb	Zr ppb	Ag ppb	B ppb	Be ppb	Li ppb	Sc ppb	Ce ppb	La ppb	Y ppb
1.-	5.-	10.-	10.-	1.-	5.0	1.-	50.-	10.-	1.-

ANALYSEUSIKKERHET: ± 20 rel. % for K, Pb, Cd, Li, Ce.
± 10 rel. % for Si, Al, Na, Mo, Cr, Zr, Ag, B og La.
± 5 rel. % for Fe, Ti, Mg, Ca, Mn, P, Cu, Zn, Ni, Co, V, Ba, Sr, Be, Sc, Y.

PRESISJON : Det kjøres rutinemessig kontrollprøver, som føres i kontrolldiagram (X-diagram). Disse kan forevises om ønskelig.

ANTALL PRØVER: 12

ANMERKNINGER: Verdi for Na i prøve 1JA3F er bestemt separat på fortynnet (1:9) prøve, ellers ingen.

Rapporten må ikke gjengis i utdrag uten skriftlig godkjenning fra NGU-Lab.

Ferdig analysert	06.08.96	Brit Inger Vongraven
	Dato	OPERATØR

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	Sv1A5F	Sv2A41	Sv2A42	Sv3A1F	Sv3DiF	Sv5A3F	Sv5A4F	Sv5Dii	SvK1F	SvK2F
Si	23.8ppm	23.4ppm	21.7ppm	23.5ppm	21.4ppm	29.3ppm	28.6ppm	28.9ppm	6.5ppm	697ppb
Al	<20.0ppb	<20.0ppb	<20.0ppb	<20.0ppb	<20.0ppb	<20.0ppb	<20.0ppb	<20.0ppb	<20.0ppb	<20.0ppb
Fe	30.8ppb	24.7ppb	28.8ppb	92.5ppb	<10.0ppb	<10.0ppb	10.3ppb	<10.0ppb	<10.0ppb	<10.0ppb
Ti	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb
Mg	33.5ppm	33.0ppm	33.0ppm	33.1ppm	29.7ppm	29.2ppm	31.1ppm	29.1ppm	12.3ppm	4.1ppm
Ca	111ppm	111ppm	104ppm	110ppm	81.3ppm	99.0ppm	88.6ppm	84.2ppm	68.8ppm	41.4ppm
Na	214ppm	212ppm	211ppm	212ppm	200ppm	288ppm	282ppm	276ppm	46.7ppm	2.4ppm
K	13.1ppm	13.0ppm	13.1ppm	13.2ppm	12.7ppm	16.6ppm	16.3ppm	16.2ppm	3.7ppm	< 500ppb
Mn	10.8ppb	14.1ppb	12.8ppb	14.1ppb	<1.00ppb	16.6ppb	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb
P	< 100ppb	< 100ppb	< 100ppb	< 100ppb	< 100ppb	< 100ppb	< 100ppb	< 100ppb	< 100ppb	< 100ppb
Cu	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	9.7ppb
Zn	< 2.0ppb	< 2.0ppb	< 2.0ppb	< 2.0ppb	< 2.0ppb	< 2.0ppb	< 2.0ppb	< 2.0ppb	< 2.0ppb	5.0ppb
Pb	<50.0ppb	<50.0ppb	<50.0ppb	<50.0ppb	<50.0ppb	<50.0ppb	<50.0ppb	<50.0ppb	<50.0ppb	<50.0ppb
Ni	<20.0ppb	<20.0ppb	<20.0ppb	<20.0ppb	<20.0ppb	<20.0ppb	<20.0ppb	<20.0ppb	<20.0ppb	<20.0ppb
Co	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb
V	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb
Mo	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb
Cd	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb
Cr	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb
Ba	112ppb	113ppb	107ppb	112ppb	96.6ppb	105ppb	96.3ppb	95.6ppb	36.5ppb	8.2ppb
Sr	1.1ppm	1.1ppm	1.1ppm	1.1ppm	957ppb	1.1ppm	1.1ppm	1.0ppm	321ppb	51.1ppb
Zr	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb	< 5.0ppb
Ag	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb
B	226ppb	228ppb	218ppb	212ppb	210ppb	331ppb	325ppb	323ppb	44.7ppb	<10.0ppb
Be	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb
Li	350ppb	350ppb	346ppb	348ppb	324ppb	456ppb	454ppb	438ppb	71.2ppb	< 5.0ppb
Sc	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb
Ce	<50.0ppb	<50.0ppb	<50.0ppb	<50.0ppb	<50.0ppb	<50.0ppb	<50.0ppb	<50.0ppb	<50.0ppb	<50.0ppb
La	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb	<10.0ppb
Y	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb	<1.00ppb

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Analysekontraktsnr:1996.0121

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	1JA3F	2JB1F
Si	60.7ppm	32.0ppm
Al	<20.0ppb	<20.0ppb
Fe	183ppb	<10.0ppb
Ti	< 5.0ppb	< 5.0ppb
Mg	29.3ppm	25.2ppm
Ca	112ppm	96.4ppm
Na	706ppm	354ppm
K	46.5ppm	25.9ppm
Mn	11.4ppb	<1.00ppb
P	< 100ppb	< 100ppb
Cu	< 5.0ppb	< 5.0ppb
Zn	< 2.0ppb	< 2.0ppb
Pb	<50.0ppb	<50.0ppb
Ni	<20.0ppb	<20.0ppb
Co	<10.0ppb	<10.0ppb
V	< 5.0ppb	< 5.0ppb
Mo	<10.0ppb	<10.0ppb
Cd	< 5.0ppb	< 5.0ppb
Cr	<10.0ppb	<10.0ppb
Ba	99.1ppb	53.0ppb
Sr	1.4ppm	939ppb
Zr	< 5.0ppb	< 5.0ppb
Ag	<10.0ppb	<10.0ppb
B	1.1ppm	601ppb
Be	<1.00ppb	<1.00ppb
Li	1.2ppm	643ppb
Sc	<1.00ppb	<1.00ppb
Ce	<50.0ppb	<50.0ppb
La	<10.0ppb	<10.0ppb
Y	<1.00ppb	<1.00ppb

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IC- ANALYSER
VANN
Analysekontraktsnr:1996.0121

NORSK AKKREDITERING
Nr. P020

7 ANIONER : F^-, Cl^-, NO_2^-, Br^-, NO_3^-, PO_4^{3-}, SO_4^{2-}

INSTRUMENT TYPE : **DIONEX IONEKROMATOGRAF 2120i**

NEDRE BESTEMMELSESGRENSER

ION	F^-	Cl^-	NO_2^-*	Br^-	NO_3^-	PO_4^{3-}	SO_4^{2-}
Nedre bestemmelsesgrense - mg/l	0.05	0.1	0.05	0.1	0.05	0.2	0.1

ANALYSEUSIKKERHET : **10 % rel. for alle ionene**

PRESISJON : Det kjøres rutinemessig kontrollprøver, som føres i kontrolldiagram (X-diagram). Disse kan forevises om ønskelig.

ANTALL PRØVER: 2

ANMERKNINGER:

* NGU-LAB er ikke akkreditert for NO_2^- *

Rapporten må ikke gjengis i utdrag uten skriftlig godkjenning fra NGU-Lab.

Ferdig analysert	28. august 1996	Egil Kvam
	Dato	OPERATØR

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IC- ANALYSER
VANN
Analysekontraktsnr: 1996.0121

NORSK AKKREDITERING
Nr. P020

Prøve Id.	**F^- [mg/l]**	**Cl^- [mg/l]**	**NO_2^- [mg/l]**	**Br^- [mg/l]**	**NO_3^- [mg/l]**	**PO_4^{3-} [mg/l]**	**SO_4^{2-} [mg/l]**
1JA3F	4.56	958	< 0.1	1.73	< 0.05	< 0.2	108
2JB1F	3.19	495	< 0.1	1.02	0.145	< 0.2	73.8

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ANALYSERAPPORT

NORSK AKKREDITERING
Nr. P020

ANALYSEKONTRAKT NR.: 1996.0188
NGU PROSJEKT NR.: 2717.00

OPPDRAGSGIVER: NGU, Varme kilder på Svalbard

ADRESSE:

TLF.: 310

KONTAKTPERSON: David Banks

PRØVETYPE: Vann
ANTALL PRØVER: 1
IDENTIFIKASJON AV PRØVER: Iflg. liste fra oppdragsgiver
PRØVER MOTTATT: 13.09.96
ANMERKNINGER: Ingen

SPESIFIKASJON AV OPPDRAGET I HENHOLD TIL ANALYSEKONTRAKT:

METODE	DOKUMENTASJON *)	OMFATTES AV AKKREDITERING
ICP-AES vann	NGU-SD 3.1	Ja
IC	NGU-SD 3.4	Ja

Denne rapporten inneholder i alt 6 sider. Rapporten må ikke gjengis i utdrag uten skriftlig godkjenning fra NGU-Lab.

Alle forhold ved prøvetaking, behandling og transport av prøvene før innlevering til NGU-Lab er underlagt oppdragsgivers ansvar. Analyseresultater framlagt i denne rapporten refererer derfor kun til det prøvematerialet som er mottatt av NGU-Lab.

Trondheim, 9. oktober 1996

Magne Ødegård (e.f.)

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*) Fortegnelse over dokumentasjon finnes i NGU-Labs Kvalitetshåndbok, NGU-SD 0.1, som kan rekvireres fra NGU-Labs sekretariat.

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ICP-AES ANALYSER
VANN
Analysekontraktsnr:1996.0188

NORSK AKKREDITERING
Nr. P020

INSTRUMENT TYPE : **Thermo Jarrell Ash ICP 61**

NEDRE BESTEMMELSESGRENSER VANNANALYSER
(For vannprøver som tynnes, blir deteksjonsgrensene automatisk omregnet).

Si ppb	Al ppb	Fe ppb	Ti ppb	Mg ppb	Ca ppb	Na ppb	K ppb	Mn ppb	P ppb
20.-	20.-	10.-	5.-	50.-	20.-	50.-	500.-	1.-	100.-
Cu ppb	Zn ppb	Pb ppb	Ni ppb	Co ppb	V ppb	Mo ppb	Cd ppb	Cr ppb	Ba ppb
5.-	2.-	50.-	20.-	10.-	5.-	10.-	5.-	10.-	2.-
Sr ppb	Zr ppb	Ag ppb	B ppb	Be ppb	Li ppb	Sc ppb	Ce ppb	La ppb	Y ppb
1.-	5.-	10.-	10.-	1.-	5.0	1.-	50.-	10.-	1.-

ANALYSEUSIKKERHET: ± 20 rel. % for K, Pb, Cd, Li, Ce.
± 10 rel. % for Si, Al, Na, Mo, Cr, Zr, Ag, B og La.
± 5 rel. % for Fe, Ti, Mg, Ca, Mn, P, Cu, Zn, Ni, Co, V, Ba, Sr, Be, Sc, Y.

PRESISJON : Det kjøres rutinemessig kontrollprøver, som føres i kontrolldiagram (X-diagram). Disse kan forevises om ønskelig.

ANTALL PRØVER: 1

ANMERKNINGER: Be rapporteres ikke p.g.a. at Be-kanalen er ustabil

Rapporten må ikke gjengis i utdrag uten skriftlig godkjenning fra NGU-Lab.

Ferdig analysert	19. september 1996	Brit Inger Vongraven
	Dato	OPERATØR

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	Sv6A1F
Si	28.3ppm
Al	<20.0ppb
Fe	62.6ppb
Ti	< 5.0ppb
Mg	28.4ppm
Ca	94.8ppm
Na	283ppm
K	16.0ppm
Mn	13.4ppb
P	< 100ppb
Cu	< 5.0ppb
Zn	< 2.0ppb
Pb	<50.0ppb
Ni	<20.0ppb
Co	<10.0ppb
V	< 5.0ppb
Mo	<10.0ppb
Cd	< 5.0ppb
Cr	<10.0ppb
Ba	110ppb
Sr	1.1ppm
Zr	< 5.0ppb
Ag	<10.0ppb
B	311ppb
Li	443ppb
Sc	<1.00ppb
Ce	<50.0ppb
La	<10.0ppb
Y	<1.00ppb

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IC- ANALYSER
VANN
Analysekontraktsnr:1996.0188

NORSK AKKREDITERING
Nr. P020

7 ANIONER : F^-, Cl^-, NO_2^-, Br^-, NO_3^-, PO_4^{3-}, SO_4^{2-}

INSTRUMENT TYPE : **DIONEX IONEKROMATOGRAF 2120i**

NEDRE BESTEMMELSESGRENSER

ION	F^-	Cl^-	NO_2^-*	Br^-	NO_3^-	PO_4^{3-}	SO_4^{2-}
Nedre bestemmelsesgrense - mg/l	0.05	0.1	0.05	0.1	0.05	0.2	0.1

ANALYSEUSIKKERHET : **10 % rel. for alle ionene**

PRESISJON : Det kjøres rutinemessig kontrollprøver, som føres i kontrolldiagram (X-diagram). Disse kan forevises om ønskelig.

ANTALL PRØVER: 1

ANMERKNINGER:

`* NGU-LAB er ikke akkreditert for NO₂⁻ *`

Rapporten må ikke gjengis i utdrag uten skriftlig godkjenning fra NGU-Lab.

Ferdig analysert	7. oktober 1996	Egil Kvam
	Dato	OPERATØR

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Norges geologiske undersøkelse
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IC- ANALYSER
VANN
Analysekontraktsnr:1996.0188

NORSK
AKKREDITERING
Nr. P020

Prøve Id.	F^- [mg/l]	Cl^- [mg/l]	NO_2^- [mg/l]	Br^- [mg/l]	NO_3^- [mg/l]	PO_4^{3-} [mg/l]	SO_4^{2-} [mg/l]
188/96 - Sv6a1F	3.58	282	< 0.05	0.778	< 0.05	< 0.2	61.9

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ANALYSERAPPORT

NORSK
AKKREDITERING
Nr. P020

ANALYSEKONTRAKT NR.: 1996.0004
NGU PROSJEKT NR.: 2717.00

OPPDRAGSGIVER: NGU, Varme Kilder - Svalbard

ADRESSE:

TLF.:

KONTAKTPERSON: David Banks

PRØVETYPE: Vann
ANTALL PRØVER: 11
IDENTIFIKASJON AV PRØVER: Iflg. liste fra oppdragsgiver
PRØVER MOTTATT: 08.01.97
ANMERKNINGER: Ingen

SPESIFIKASJON AV OPPDRAGET I HENHOLD TIL ANALYSEKONTRAKT:

METODE	DOKUMENTASJON *)	OMFATTES AV AKKREDITERING
IC	NGU-SD 3.4	Ja

Denne rapporten inneholder i alt 4 sider. Rapporten må ikke gjengis i utdrag uten skriftlig godkjenning fra NGU-Lab.

Alle forhold ved prøvetaking, behandling og transport av prøvene før innlevering til NGU-Lab er underlagt oppdragsgivers ansvar. Analyseresultater framlagt i denne rapporten refererer derfor kun til det prøvematerialet som er mottatt av NGU-Lab.

Trondheim, 13. januar 1997

Magne Ødegård (e.f.)

*) Fortegnelse over dokumentasjon finnes i NGU-Labs Kvalitetshåndbok, NGU-SD 0.1, som kan rekvireres fra NGU-Labs sekretariat.

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IC- ANALYSER
VANN
Analysekontraktsnr: 1997.0004

NORSK
AKKREDITERING
Nr. P020

7 ANIONER : F^-, Cl^-, NO_2^-, Br^-, NO_3^-, PO_4^{3-}, SO_4^{2-}

INSTRUMENT TYPE : **DIONEX IONEKROMATOGRAF 2120i**

NEDRE BESTEMMELSESGRENSER

ION	F^-	Cl^-	NO_2^-*	Br^-	NO_3^-	PO_4^{3-}	SO_4^{2-}
Nedre bestemmelsesgrense - mg/l	0.05	0.1	0.05	0.1	0.05	0.2	0.1

ANALYSEUSIKKERHET : **10 % rel. for alle ionene**

PRESISJON : Det kjøres rutinemessig kontrollprøver, som føres i kontrolldiagram (X-diagram). Disse kan forevises om ønskelig.

ANTALL PRØVER: 11

ANMERKNINGER: Ingen

`* NGU-LAB er ikke akkreditert for NO₂⁻ *`

Rapporten må ikke gjengis i utdrag uten skriftlig godkjenning fra NGU-Lab.

Ferdig analysert	9. januar 1997	Egil Kvam
	Dato	OPERATØR

NGU
Norges geologiske undersøkelse

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Tlf.: 73 90 40 11
Telefaks: 73 92 16 20

IC- ANALYSER
VANN

Analysekontraktsnr:1997.0004

NORSK AKKREDITERING
Nr. P020

Prøve Id.	F^- [mg/l]	Cl^- [mg/l]	NO_2^- [mg/l]	Br^- [mg/l]	NO_3^- [mg/l]	PO_4^{3-} [mg/l]	SO_4^{2-} [mg/l]
4/97 - 1	3.87	221	< 0.05	0.534	0.229	< 0.2	57.2
4/97 - 2	3.32	144	< 0.05	0.412	< 0.05	< 0.2	49.2
4/97 - 3	3.29	147	< 0.05	0.413	< 0.05	< 0.2	49.5
4/97 - 4	3.26	150	< 0.05	0.386	< 0.05	< 0.2	50.7
4/97 - 5	3.21	135	< 0.05	0.365	0.180	< 0.2	46.4
4/97 - 6	3.35	147	< 0.05	0.408	< 0.05	< 0.2	52.9
4/97 - 7	3.97	220	< 0.05	0.581	< 0.05	< 0.2	56.6
4/97 - 8	3.93	228	< 0.05	0.631	0.212	< 0.2	55.3
4/97 - 9	3.92	216	< 0.05	0.552	0.183	< 0.2	56.0
4/97 - 10	0.917	29.1	< 0.05	< 0.1	0.226	< 0.2	15.8
4/97 - 11	0.103	4.76	< 0.05	< 0.1	< 0.05	< 0.2	7.16

4

ID numbers as in Appendix 2

Appendix 2

Analytical results - anions-from Norges Landbrukshøyskole (filtered [0. 45μm], unacidified water samples)

also laboratory determinations of pH, electrical conductivity and alkalinity at NLH

Prøvemerking
1: Sv5A4
2: Sv2A4i
3: Sv2A4ii
4: Sv3A1
5: Sv3Di
6: Sv1A5
7: Sv6A1
8: Sv5A3
9: Sv5Dii
10: SvK1
11: SvK2

LABORATORIUM FOR ANALYTISK KJEMI (LAK-KA) - NLH
Boks 5031
1432 ÅS

DATO:961205

ANALYSEBEVIS for rekvisisjon nr: 960430

JORD- OG VANNFAG (B Swensen)
Boks 5028

0 HER

Kontaktperson: BERIT SWENSEN

11 vann

Rekvisisjonens registreringsdato: 960912

Laboratoriet oppbevarer prøvene i en måned etter at oppdraget er fullført

Analyseresultatet er oppgitt med inntil tre gjeldende siffer

Merknader:

ANALYSEBEVIS FRA LABORATORIUM FOR ANALYTISK KJEMI (LAK-KA) - NLH Rekvisisjon 960430 Side: 1

Journr	Mrk	Nitrat-N	Vannl-P	Sulfat-S	Vannl-Cl
438980	1	<0.1 mg/l	<0.1 mg/l	26. mg/l	210. mg/l
438981	2	<0.1	<0.1	22	140
438982	3	<0.1	<0.1	22	145
438983	4	<0.1	<0.1	21	145
438984	5	<0.1	<0.1	20	140
438985	6	<0.1	<0.1	21	150
438986	7	<0.1	<0.1	24	210
438987	8	<0.1	<0.1	25	215
438988	9	<0.1	<0.1	24	210
438989	10	<0.1	<0.1	7.6	34
438990	11	<0.1	<0.1	4.6	5.0

Frank Antonsen

F:

J.nr. 210/96 Mottatt: 12.8 96 Rekvirent: B. Swensen

Institutt/Seksjon: Ferdig: Adresse:

Prøvene står på kjølerom hos IJAW i kjelleren.

Analyser som ønskes utført. (Kryss av på venstre side i rubrikken)

L.nr.	Pr.mrk.	pH	ledn.	alk.
1	Sv5A4			
2	Sv2A4i			
3	Sv2A4ii			
4	Sv3A1			
5	Sv3Di			
6	Sv1A5			
7	Sv6A1			
8	Sv5A3			
9	Sv5Dii			
10	SvK1			
11	SvK2			

Ark1

Berit Swensen

Rekv. 210/96		ms.	meq/l
	pH	ledn.evne	alk.
Pr.nr. 1	7.76	1.838	11.75
2	7.86	1.496	10.75
3	7.79	1.581	10.90
4	7.45	1.630	11.75
5	8.04	1.408	9.75
6	7.54	1.607	11.75
7	7.50	1.914	12.75
8	7.32	1.942	12.90
9	7.76	1.830	11.50
10	8.05	1.612	5.25
11	8.08	0.242	2.15

E:

Appendix 3

Analytical results from BGR, Germany
ICP-MS (filtered [0.45μm], acidified water samples)

¢1m

Probenidentifikation				Ag	Al	As	B	Ba	Be	Bi	(Br)	(Ca)	Cd	Ce	Co
¢22m															
IM14360	44155/01	SV	1A5 FS	0.001	-0.1	0.25	188	112	0.33	0.001	476	103000	0.044	0.01	0.075
IM14361	44155/02	SV	2A41FS	-0.001	1.05	1.03	223	111	0.4	-0.001	487	120000	0.015	0.006	0.4
IM14362	44155/03	SV	3A1 FS	-0.001	-0.1	0.93	238	112	0.4	-0.001	486	126000	0.008	0.027	0.22
IM14363	44155/04	SV	5A3 FS	0.001	1.41	0.15	391	97	0.23	-0.001	751	111000	0.006	0.001	0.044
IM14364	44155/05	SV	5A4 FS	0.001	0.12	0.19	359	98.7	0.38	0.002	697	108000	0.011	0.001	0.088
IM14365	44155/06	SV	5Dii FS	0.001	0.73	0.26	377	99.3	0.2	-0.001	698	104000	0.012	0.001	0.029
IM14366	44155/07	SV	6A1 FS	0.001	2.3	0.036	372	115	0.56	0.002	697	120000	0.008	0.059	0.043
IM14367	44155/08	SV	K1 FS	0.001	1.15	1.5	68.7	38.1	0.084	-0.001	103	87900	0.008	0.015	0.022
IM14368	44155/09	SV	K2 FS	0.031	8.13	0.48	6.75	9.62	0.019	0.001	17.1	53000	0.03	0.025	0.034
IM14369	44155/10	SV	1JA3 FS	0.003	-0.1	0.42	969	97.7	0.65	0.002	2680	127000	0.011	0.001	0.062
IM14370	44155/11	SV	2JB1 FS	0.002	3.76	6.17	605	53.3	0.2	0.004	1420	116000	0.012	0.005	0.023
IM14371	44155/12	SV	BLANK 1	-0.001	-0.1	0.014	-0.01	0.013	-0.002	-0.001	0.33	13.6	-0.002	0.001	-0.002
IM14372	44155/13	SV	BLANK 2	-0.001	-0.1	-0.01	-0.01	-0.005	-0.002	-0.001	0.32	-1	-0.002	0.001	0.006

minus sign denote below detection limit: i.e. -1 means < 1

¢1m

Probenidentifikation				Cr	Cs	Cu	(Fe)	Ga	(Ge)	Hf	Hg	In	(I)	(K)	La
¢22m															
IM14360	44155/01	SV	1A5 FS	1.14	27.1	0.28	15.2	0.015	9.39	0.32	-0.005	-0.001	9.89	13700	0.008
IM14361	44155/02	SV	2A41FS	1.47	27	0.29	29.5	0.015	9.47	0.045	-0.005	-0.001	6.27	15600	0.007
IM14362	44155/03	SV	3A1 FS	1.32	27.6	0.24	22	0.016	9.62	0.16	-0.005	-0.001	11.1	15900	0.016
IM14363	44155/04	SV	5A3 FS	3.57	38.1	0.28	39.2	0.014	15	0.056	0.008	-0.001	10.7	20800	0.001
IM14364	44155/05	SV	5A4 FS	2.25	35.6	0.28	45.7	0.012	14	0.01	0.006	-0.001	17.2	20800	0.001
IM14365	44155/06	SV	5Dii FS	3.14	39.8	0.24	29.2	0.012	14.4	0.028	-0.005	-0.001	16.8	20700	0.001
IM14366	44155/07	SV	6A1 FS	2.25	37.9	0.64	61.6	0.018	14.2	0.19	-0.005	-0.001	30.6	20600	0.032
IM14367	44155/08	SV	K1 FS	0.45	6.55	4.32	39.1	0.011	1.99	0.013	-0.005	-0.001	7.73	5310	0.028
IM14368	44155/09	SV	K2 FS	0.23	0.017	11.8	50.5	0.016	0.002	-0.002	-0.005	-0.001	1.05	1130	0.015
IM14369	44155/10	SV	1JA3 FS	2.18	142	0.34	38.5	0.011	25.8	0.015	0.027	-0.001	76.3	54300	0.002
IM14370	44155/11	SV	2JB1 FS	0.9	48.8	0.25	25.4	0.013	9.5	0.073	-0.005	-0.001	33.2	30500	0.007
IM14371	44155/12	SV	BLANK 1	-0.005	-0.001	0.48	-1	-0.001	-0.002	-0.002	0.012	-0.001	-0.1	7.98	-0.001
IM14372	44155/13	SV	BLANK 2	0.019	-0.001	0.16	-1	-0.001	-0.002	-0.002	0.011	-0.001	-0.1	-1	-0.001

¢1m

Probenidentifikation				Li	(Mg)	Mn	Mo	(Na)	Nb	Ni	(PO4)	Pb	Rb	Sb	Sc
¢22m															
IM14360	44155/01	SV	1A5 FS	287	30900	11.1	0.31	348000	0.01	0.25	3.31	0.031	83.3	-0.002	7.13
IM14361	44155/02	SV	2A41FS	324	35700	16	0.36	350000	0.021	0.26	7.87	0.021	83	0.018	8.43
IM14362	44155/03	SV	3A1 FS	343	40300	15.1	0.32	352000	0.019	0.17	7.27	0.008	83.5	-0.002	8.63
IM14363	44155/04	SV	5A3 FS	484	36900	13.5	0.18	354000	0.093	0.2	21.2	0.002	110	0.064	12.1
IM14364	44155/05	SV	5A4 FS	467	38600	2.02	0.22	356000	0.019	0.25	12.7	0.006	104	0.026	11.5
IM14365	44155/06	SV	5Dii FS	468	35600	0.021	0.23	358000	0.081	0.22	16.3	0.006	108	0.035	11.8
IM14366	44155/07	SV	6A1 FS	468	35600	14.4	0.15	360000	0.084	0.18	11.6	0.07	105	0.005	10.8
IM14367	44155/08	SV	K1 FS	89.8	14900	0.016	0.23	53200	0.014	0.3	7.54	0.018	19.7	0.055	0.91
IM14368	44155/09	SV	K2 FS	1.52	4910	0.16	0.11	2930	0.011	0.29	7.3	0.36	0.21	0.039	0.45
IM14369	44155/10	SV	1JA3 FS	1030	33100	11.7	0.04	366000	0.011	0.32	22.4	0.002	341	0.019	20.6
IM14370	44155/11	SV	2JB1 FS	629	29500	-0.01	1.56	368000	0.022	0.39	16.4	0.15	168	0.078	11.1
IM14371	44155/12	SV	BLANK 1	0.043	5.54	-0.01	0.001	-1	-0.002	-0.002	-1	0.047	0.002	0.007	0.017
IM14372	44155/13	SV	BLANK 2	0.016	5.26	-0.01	0.002	-1	0.07	-0.002	-1	-0.002	-0.002	0.016	-0.005

¢1m

Probenidentifikation				Se	Sn	Sr	Ta	Te	Th	Ti	Tl	U	V	W	Y
¢22m															
IM14360	44155/01	SV	1A5 FS	2.26	0.022	1140	0.019	0.002	0.021	0.69	0.004	0.41	0.3	1.6	0.086
IM14361	44155/02	SV	2A41FS	0.89	0.017	1130	0.029	0.012	0.003	0.64	0.007	0.18	0.34	1.95	0.034
IM14362	44155/03	SV	3A1 FS	1.32	0.007	1110	0.004	0.006	0.014	0.84	0.006	0.51	0.36	1.41	0.11
IM14363	44155/04	SV	5A3 FS	1.04	0.003	1130	0.054	0.011	0.003	0.87	0.006	0.42	0.59	5.75	0.008
IM14364	44155/05	SV	5A4 FS	1.19	0.004	1130	0.026	0.01	0.001	0.89	0.007	0.12	0.65	5.03	0.009
IM14365	44155/06	SV	5Dii FS	0.57	0.004	1110	0.085	0.018	0.001	0.99	0.007	0.48	0.63	4.06	0.009
IM14366	44155/07	SV	6A1 FS	1.36	0.016	1150	0.018	0.009	0.021	1.1	0.004	0.33	0.58	4.37	0.16
IM14367	44155/08	SV	K1 FS	0.63	-0.002	325	0.001	0.005	0.002	0.42	0.004	0.62	0.17	0.45	0.088
IM14368	44155/09	SV	K2 FS	0.14	0.014	50.6	0.001	0.005	0.002	0.83	0.002	0.41	0.12	-0.002	0.036
IM14369	44155/10	SV	1JA3 FS	0.83	0.004	1430	0.009	0.005	0.001	1.34	0.005	0.005	0.45	14.3	0.017
IM14370	44155/11	SV	2JB1 FS	1.85	0.01	953	0.004	0.013	0.005	0.91	0.016	2.36	0.51	3.24	0.03
IM14371	44155/12	SV	BLANK 1	0.13	0.003	-0.01	0.007	-0.001	-0.001	-0.1	-0.002	0.001	-0.01	0.002	-0.001
IM14372	44155/13	SV	BLANK 2	0.53	-0.002	-0.01	0.006	-0.001	-0.001	0.18	-0.002	-0.001	-0.01	0.051	0.001

¢1m

Probenidentifikation				Zn	Zr	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm
¢22m															
IM14360	44155/01	SV	1A5 FS	1.55	0.38	0.001	0.008	0.004	0.004	0.004	0.001	0.006	0.001	0.004	-0.001
IM14361	44155/02	SV	2A41FS	1.44	0.043	-0.001	0.002	0.002	0.003	0.001	-0.001	-0.001	-0.001	0.003	-0.001
IM14362	44155/03	SV	3A1 FS	0.74	0.16	0.004	0.017	0.004	0.005	0.008	0.001	0.012	0.002	0.01	0.001
IM14363	44155/04	SV	5A3 FS	24.4	0.069	-0.001	-0.001	-0.001	0.002	0.001	-0.001	-0.001	-0.001	-0.001	-0.001
IM14364	44155/05	SV	5A4 FS	253	0.011	-0.001	0.001	-0.001	0.003	0.001	-0.001	-0.001	-0.001	0.001	-0.001
IM14365	44155/06	SV	5Dii FS	7.92	0.034	-0.001	0.002	0.002	0.006	0.001	-0.001	-0.001	-0.001	-0.001	-0.001
IM14366	44155/07	SV	6A1 FS	1.68	0.21	0.007	0.029	0.009	0.011	0.01	0.002	0.016	0.003	0.014	0.002
IM14367	44155/08	SV	K1 FS	38.6	0.019	0.006	0.03	0.007	0.001	0.008	0.001	0.009	0.002	0.006	0.001
IM14368	44155/09	SV	K2 FS	57.2	0.01	0.004	0.017	0.006	0.001	0.006	0.001	0.006	0.001	0.003	-0.001
IM14369	44155/10	SV	1JA3 FS	2.25	0.008	-0.001	-0.001	0.001	0.008	-0.001	-0.001	-0.001	0.001	0.001	-0.001
IM14370	44155/11	SV	2JB1 FS	7.95	0.12	0.002	0.004	0.001	0.003	0.003	0.001	0.002	0.001	0.002	0.001
IM14371	44155/12	SV	BLANK 1	1.63	-0.002	-0.001	-0.001	-0.001	-0.001	0.001	-0.001	-0.001	-0.001	-0.001	-0.001
IM14372	44155/13	SV	BLANK 2	0.71	0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001

¢1m

Probenidentifikation				Yb	Lu
¢22m					
IM14360	44155/01	SV	1A5 FS	0.005	0.001
IM14361	44155/02	SV	2A41FS	0.002	-0.001
IM14362	44155/03	SV	3A1 FS	0.009	0.001
IM14363	44155/04	SV	5A3 FS	0.001	-0.001
IM14364	44155/05	SV	5A4 FS	0.002	-0.001
IM14365	44155/06	SV	5Dii FS	-0.001	-0.001
IM14366	44155/07	SV	6A1 FS	0.01	0.002
IM14367	44155/08	SV	K1 FS	0.007	0.002
IM14368	44155/09	SV	K2 FS	0.005	0.001
IM14369	44155/10	SV	1JA3 FS	0.001	-0.001
IM14370	44155/11	SV	2JB1 FS	0.004	0.001
IM14371	44155/12	SV	BLANK 1	-0.001	-0.001
IM14372	44155/13	SV	BLANK 2	-0.001	-0.001

Appendix 4

Field analyses by David Banks and Ron S. Sletten

Alkalinity was measured by field titration against 0.1 N acid, using a mixed indicator with end-point at 4,3. At each spring 3 titrations were performed and the average presente
Ron S. has the complete set of T, pH and Eh measurements
Bubbling: Cont. = Continuously, Epi. = Episodically / Intermittently,

Date	Spring	Alkalinity (meq/l)	Alkalinity (meq/l	Eh	pH	T	Bubbling ?		Runoff
		Indiv Readings	Average	mV		°C			
14/07/96	1A5	14.0		-175		21.7	Epi.		No
		13.0	13.2						
		12.7							
14/07/96	2A4i	12.9					Epi.		to 2A4ii
		13.5	13.2						
		13.1							
14/07/96	2A4ii	13.8					Cont.		No
		12.9	13.2						
		13.0							
14/07/96	3A1	13.0					Epi.	Nasally detectable H2S	1 to 2 l/s
		13.0	13.1						
		13.2							
14/07/96	3Di	11.3					No	Spring reemergence	Yes
		11.2	11.3					at river level	
		11.5							
14/07/96	K1	5.3					No	Cold spr. between 3 & 4	0,3-0,5 l/s
		5.4	5.4						
		5.5							
14/07/96	K2	2.2			7.98	0.5	No	Cold spr. up slope	Yes
		2.2	2.2					between 4 & 5	
		2.3							
14/07/96	5A1						Epi.		No
14/07/96	5A2						Epi.		No
14/07/96	5A3	13.6					Epi.		No
		13.5	13.5						
		13.5							
14/07/96	5A4	13.4					Epi.		Yes
		13.8	13.6						
		13.7							
14/07/96	5Dii	12.9					No	Spring reemergence	Yes
		12.8	12.9					at river level	
15/07/96	6A1	13.5		+ 70	6.69	20.0	No		Yes
		13.4	13.7						
		14.1							
15/07/96	6A2			+105-110	6.69	20.0			Very little
16/07/96	1JA1			- 170	6.71	21.9	Epi.	Jotunkilde 1, A position	Very little
16/07/96	1JA2			- 160	6.69	21.8	No	Jotunkilde 1, A position	Very little
16/07/96	1JA3			- 100	6.67	23.0	Epi.	Jotunkilde 1, A position	Yes
16/07/96	1JA3 (after sediment sampled & disturbed)			- 250		23.3			
16/07/96	2JB			+ 200	7.08	13.8	No	Jotunkilde 2, B position	c. 0.05 l/s

Data entry checked by DB 31/7/96

Runoff = surface run-off from spring area. It is assumed that most springs have groundwater runoff by reinfiltration of water into travertine deposits.

Epi. = epsisodic

Idnr	*Spring	Type	Alk_field	Eh_DB	Eh_Ron	Eh_field	pH_DB	pH_Ron	pH_field	T_DB	T_Ron	T_field	*Bubbling	*Commen	*Runoff
1	1A1	1	-9999.99	-9999.99	178	178	-9999.99	6.91	6.91	-9999.99	12.9	12.9	-9999.99	-9999.99	-9999.99
2	1A2	1			117	117		8.11	8.11		9.7	9.7			
3	1A5	1	13.2	-175	-220	-220		6.80	6.80	21.7	21.6	21.6	Epi.		No
4	1B1	3									7.2	7.2			
5	1B2	3									11.3	11.3			
6	1B3	3									17.8	17.8			
7	1B3'	3									8.0	8.0			
8	1B4	3			120	120		6.95	6.95		17.2	17.2			
9	1C1	5			-235	-235		7.03	7.03		13.4	13.4			
10	2A2	1			-100	-100		7.78	7.78		10.2	10.2			
11	2A3	1			-150	-150		6.79	6.79		22.8	22.8			
12	2A4i	1	13.2		-240	-240		6.68	6.68		22.5	22.5	Epi.		to 2A4ii
13	2A4ii	1	13.2		-60	-60		7.19	7.19		13.4	13.4	Cont.		No
14	3A1	1	13.1		-273	-273		6.83	6.83		25.6	25.6	Epi.	Nasally d	1 to 2 l/s
15	3A2	1			-33	-33		7.60	7.60		19.6	19.6			
16	3A3	1			-24	-24		8.18	8.18		9.8	9.8			
17	3Di	6	11.3		216	216		7.65	7.65		9.5	9.5	No	Spring ree	Yes
18	3Dii	6			209	209		7.34	7.34		12.1	12.1			
19	K1	7	5.4		203	203		7.00	7.00		3.6	3.6	No	Cold spr.	0,3-0,5 l/s
20	K2	8	2.2		230	230	7.98	7.97	7.97	0.5	0.2	0.2	No	Cold sprin	Yes
21	5A1	1			259	259		6.94	6.94		18.2	18.2	Epi.		No
22	5A2	1			203	203		6.83	6.83		19.1	19.1	Epi.		No
23	5A3	1	13.5		133	133		6.78	6.78		19.4	19.4	Epi.		No
24	5A4	1	13.6		159	159		7.47	7.47		14.5	14.5	Epi.		Yes
25	5B1	3			160	160		7.10	7.10		12.2	12.2			
26	5Dii	6	12.9		160	160		7.18	7.18		11.8	11.8	No	Spring ree	Yes
27	6A1	1	13.7	70		70	6.69		6.69	20.0		20.0	No		Yes
28	6A2	1		107		107	6.69		6.69	20.0		20.0			Very little
29	1JA1	2		-170		-170	6.71		6.71	21.9		21.9	Epi.	Jotunkilde	Very little
30	1JA2	2		-160		-160	6.69		6.69	21.8		21.8	No	Jotunkilde	Very little
31	1JA3	2		-100		-100	6.67		6.67	23.0		23.0	Epi.	Jotunkilde	Yes
32	1JA3 (b)	2		-250		-250				23.3		23.3		(after sediment samp	
33	2JB	4		200		200	7.08		7.08	13.8		13.8	No	Jotunkilde	c. 0.05 l/s

This file was taken from the checked svalbalk main spreadsheet 15/1/97 and used for the creation of svmajdas.wks on the same date

-9999.99 = no data

Type: 1 = A spring Troll, 2 = A spring Jotun, 3 = B spring Troll, 4 = B spring Jotun, 5 = C spring Troll, 6 = D spring Troll, 7 = K1 spring Troll, 8 = K2 spring Troll

Appendix 5

Rock analyses from BGR

(i) Summary and comparison of rock analyses
(ii) Rock sample list
(iii) XRF analysis results
(iv) ICP-MS analysis results

(i) Whole Rock Trace Geochemistry; Bockfjord, Svalbard. Summary and Comparison of XRF and ICP-MS Techniques.

Sample Selection

The Bockfjord area of northern Spitsbergen is the site of what are believed to be the world's northernmost thermal springs (Hoel & Holtedahl 1913, Liestøl 1976, Banks et al. 1997, *in prep.*). The springs arise from a fault zone separating Upper Hecla Hoek Precambrian age mica schists and marbles from the Devonian "Old Red Sandstones" of the Wood Bay / Red Bay Series (Friend 1961, Hjelle 1993). Travertine basins have been formed associated with fossil (inactive) and current (active) thermal springs. Eleven samples of rock were collected from the Bockfjord spring areas in July 1996, as follows:.

Sv1R - Grey, fine-grained, Hecla Hoek marble from Trollkildene
Sv3R - Travertine from an active travertine mound, Spring 5A4, Trollkildene
Sv5R - Buff brecciated Hecla Hoek marble from Trollkildene
Sv10R - Red-brown travertine from a fossil basin, spring area 1, Trollkildene.
Sv11Ra - Travertine from laminar layers in the wall of a fossil travertine basin, spring area 3, Trollkildene
Sv11Rb - Travertine from porous layers in the wall of a fossil travertine basin, spring area 3, Trollkildene
Sv14R - Fossil travertine, spring area 7, Trollkildene.
Sv15R - Travertine from active basin, spring area 3, Trollkildene
Sv17R - Greyish, coarser-grained marble, Hecla Hoek, Jotunkildene
Sv19R - Frost-shattered mica-schist the Hecla Hoek, Jotunkildene
Sv28R - Devonian Old Red Sandstone, near Trollkildene

XRD analysis of travertine samples Sv3R, Sv10R and Sv15R showed them to be almost exclusively composed of calcite.

Sample Preparation and Analysis

At the Geological Survey of Norway, samples were prepared by crushing and fine milling in a clean agate mill. Further sample preparation and analysis were performed at the Bundesanstalt für Geowissenschaften und Rohstoffe in Germany.

For X-Ray Fluorescence (XRF) analysis, 1000 mg of milled samples were heated to 1030°C for 15 minutes to determine loss on ignition. After mixing the residue with 5.0 g lithium metaborate and 100 mg iodine pentoxide, the samples were fused at 1150°C for 20 minutes in

Pt-Au crucibles to produce glassy XRF discs (Török & van Grieken 1992, Török et al. 1996). Analysis was performed using a wavelength dispersive X-ray spectrometer, with both chromium (PW 1480) and rhodium (PW 1400) tubes to achieve optimal results for different elements. Monitor samples and more than 50 certified reference materials were used for calibration and matrix correction (de Jongh's alpha-correction) of results.

For Inductively Coupled Plasma Mass Spectrometry (ICP-MS) analysis, 100 mg of milled sample was added to 5 ml of concentrated ultrapure HNO_3 and 2 ml HF. The mixture was heated at 170°C for 24 hours in a sealed Teflon bomb. The reaction vessel was then carefully opened and heated to near-dryness on a hotplate. 3 ml of concentrated HCl was added and samples were again heated in the sealed vessel at 150°C for 12 hrs. Finally 1 ml HNO_3 and 1 ml HCl were added to the residue and the solution topped up with pure water to 100 g total (i.e. a total dilution factor of 1000), prior to ICP-MS analysis using the instrument described in Reimann et al. (1996), who also cite detection limits for aqueous solutions of each element. For both XRF and ICP-MS analyses, results are cited as ppm relative to dry, non-ignited weight.

Results and Discussion

The results are presented as x-y plots of XRF versus ICP-MS results for trace elements, all in ppm (Fig. 13). In many cases, XRF results fall below cited detection limits. In these cases, the values are plotted at half the detection limit and the detection limit is shown by an arrow. For the elements Bi, Mo, Sb and W, results obtained by the two techniques were of completely differing orders of magnitude. This is to be expected as such elements may be lost by volatilization, e.g. as volatile fluorides or chlorides during acid dissolution and heating for ICP-MS analysis (in fact, fluorides of W and Mo and a chloride of Sb have boiling points significantly under 100°C - Lide 1991).

Values obtained by the two techniques are of similar orders of magnitude for Cu, Hf, La, Sn and U, but correlations were poor. For As, Ce, Nb, Sc and V, good correlations are achieved at high concentrations, but at low concentrations the correlations are poorer. Good correlations between XRF and ICP-MS were obtained for Ba, Co, Cr, Ga, Mn, Ni, Pb, Rb, Sr, Th, Ti and Zn. In the case of Zr, a reasonable correlation was also obtained, though with generally lower values from ICP-MS, probably reflecting difficulties in total solution of, for example, zircon minerals in the ICP-MS digestion procedure.

The travertines, composed of almost pure calcite, show the lowest concentrations of most trace elements, followed by the marbles. The schist and sandstone generally yield the highest values. Exceptions include Ba, where the travertines are enriched compared to the marbles. In the case of Sr, the travertines reflect the Sr-enriched (though strontianite-undersaturated) nature of the thermal waters themselves (Fig. 14). The thermal waters are saturated with respect to barite so it is possible that the travertines contain traces of this mineral. As XRD analysis did not indicate the presence of Sr or Ba minerals, however, it is regarded as more likely that these elements are substituting for chemically analogous Ca in the calcite lattice.

In conclusion, the results of this comparative study confirm that ICP-MS analysis of acid digests of rock samples is a satisfactory means of determining whole rock contents of most trace elements, in comparison with XRF and considering the wide range of parameters determined by both methods. In the majority of cases, ICP-MS is capable of achieving considerably lower detection limits than XRF. Discrepancies between the techniques may be due to (i) volatilisation during preparation, (ii) matrix effects or interference with other elements, (iii) incomplete digestion of some minerals (e.g. zircon) during preparation. Discrepancies could be minimised by tailoring preparation techniques and interference correction algorithms to the elements of most interest.

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Note: In Figure 13 and 14, points below detection limit are plotted at a value corresponding to half the detection limit. This is a purely artificial means of registering the fact that the analysis returning a "<" value and has NO correspondence to an actual concentration. This fact may give a misleading visual impression of a correlation (or lack of correlation) where such is, in fact, not necessarily the case.

Figure 13. Analyses of rock samples from Svalbard for trace elements by XRF (x-axis) and ICP-MS (y-axis). All cited as ppm relative to dry, non-ignited weight. For each element, two figures are cited near the top of each box: the upper represents the best fit linear correlation coefficient (r); the lower is the slope of the best fit regression line. Arrows show analytical detection limit.

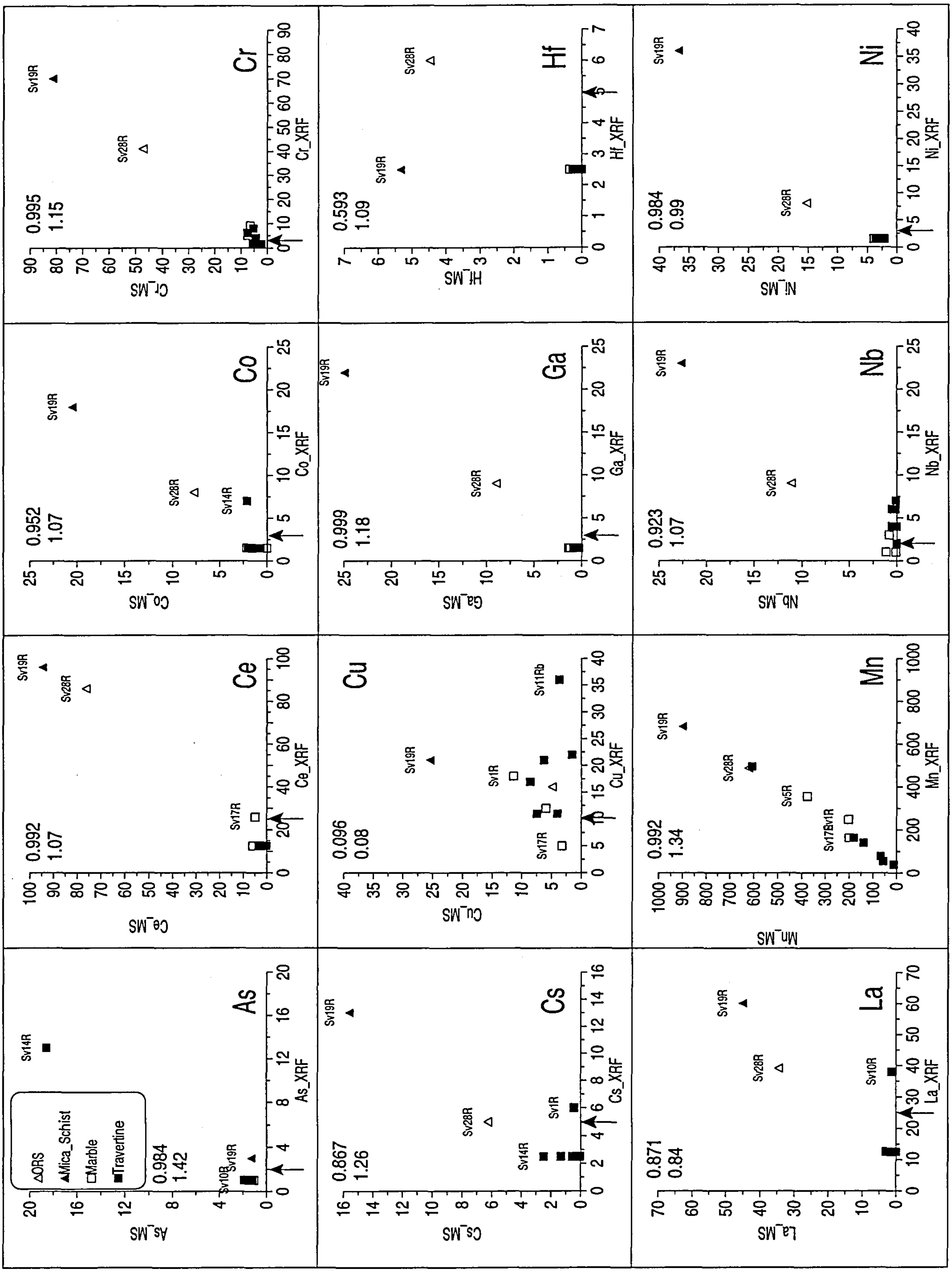


Figure 13 (continued).

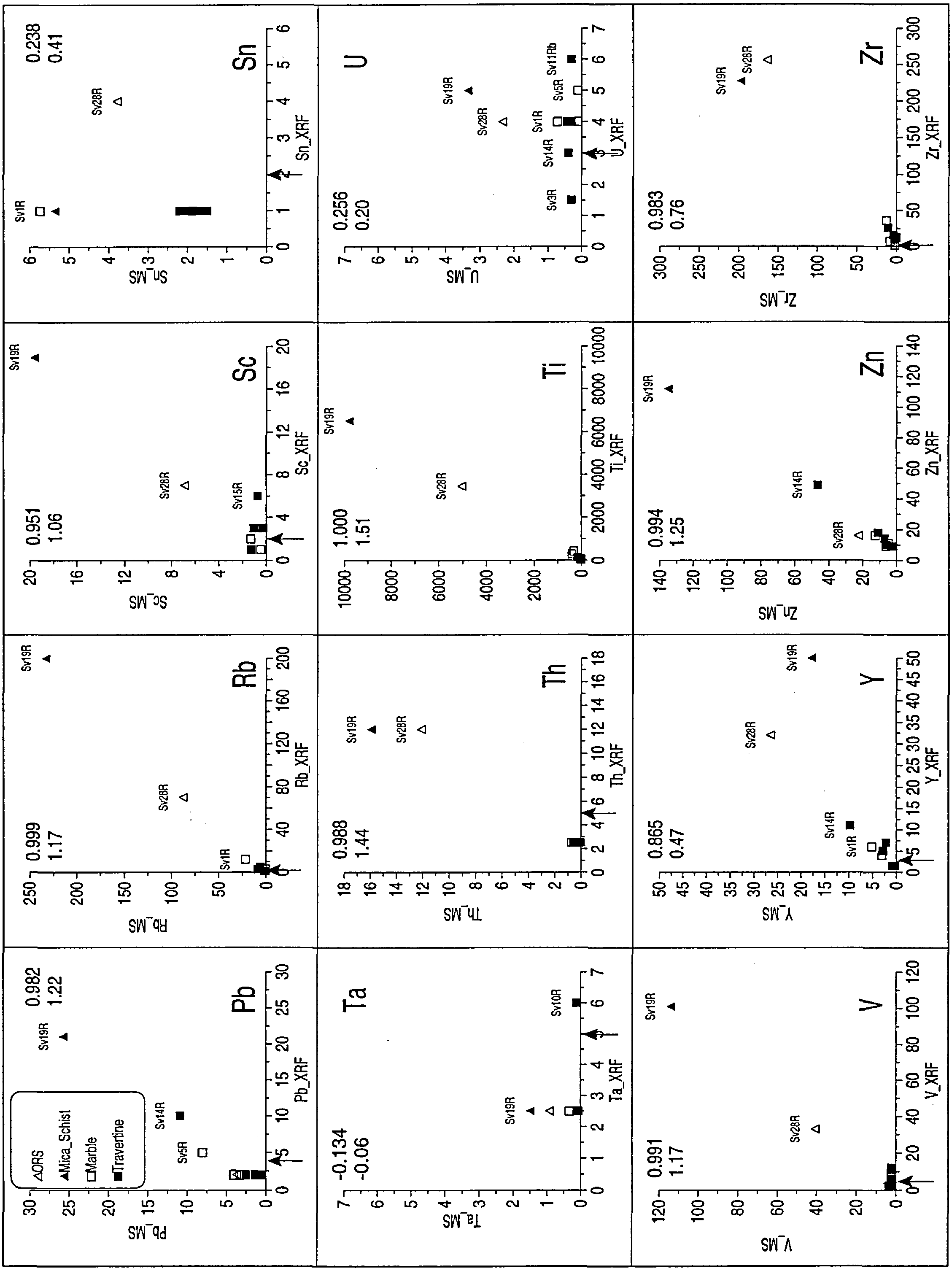
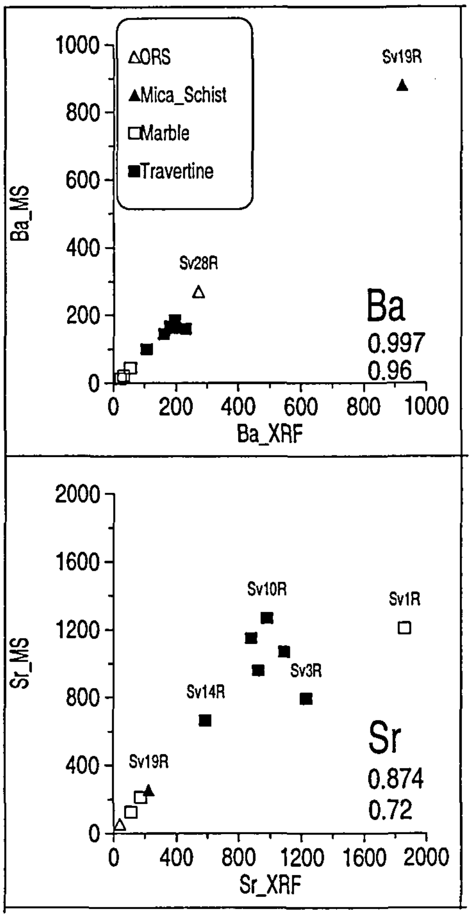


Figure 14. Analyses of rock samples from Svalbard for Ba and Sr by XRF (x-axis) and ICP-MS (y-axis), all cited as ppm relative to dry, non-ignited weight. For each element, two figures are cited near the bottom of each box: the upper represents the best fit linear correlation coefficient (r); the lower is the slope of the best fit regression line.

Note: in Figures 13 and 14, the correlation coefficients are of little meaning where a significant proportion of samples lie below the detection limit.



Comments on Appropriateness of Analytical Techniques, from the Analyst (Ulrich Siewers, BGR, Germany)

Uranium :
The range of values for only eleven samples with XRF is < 3 to 6 ppm. At the detection limits it is generally agreed upon that an error of 100 per cent may appear, so one cannot rely on uranium in this range. Also, the limit of detection is, by definition, different to the limit of quantification. ICP-MS data are to be preferred.

Vanadium :
The range of values for only eleven samples with XRF is < 5 to 101 ppm. It is thus only justifiable to compare two samples giving 33 ppm and 101 ppm respectively. for XRF with ICP-MS.

Tungsten :
The range of values for only eleven samples with XRF is < 3 to 14 ppm. If scheelite ($CaWO4$) occurs in the sample, it will be difficult to attain total dissolution with acids, so the XRF data are to be preferred over ICP-MS. The variance between XRF and ICP-MS data may show this effect, but it may also be due to tungsten minerals being distributed inhomogeneously in the samples (for XRF analyses a 1000 mg sample is used, for ICP-MS only 100 mg).

Yttrium :
The range of values for only eleven samples with XRF is < 3 to 50 ppm, with only three values which are justified for use in comparison, namely 11, 32 and 50 ppm. If xenotime ($YPO4$) occurs in the sample, it will be difficult to attain total dissolution with acids (this could for example explain the discrepancy in sample SV19R), so XRF data are to be preferred.

Zinc :
No problem.

Zirconium :
If $ZrSiO4$ occurs in the sample, it will be difficult to attain total dissolution with acids, particularly if the sample contains good crystals, rather than tiny weathered ones. XRF data are to be preferred.

Molybdenum :
XRF data are to be preferred. $MoF4$ may be volatile and Mo may precipitate in an acid solution.

Niobium :
The range of values for only eleven samples with XRF is < 2 to 23 ppm, with only three values which can be used for comparison, namely 7, 9 and 23 ppm. Some Nb-containing minerals cannot be totally dissolved in acid.

Nickel :
The range of values for only eleven samples with XRF is < 3 to 36 ppm, with only two values which can be used for comparison, namely 8 and 36 ppm.

Lead :
The range of values for only eleven samples with XRF is < 4 to 21 ppm, with only two values which can be used for comparison, namely 10 and 21 ppm.

Rubidium :
the range of values for only eleven samples with XRF is < 2 to 200 ppm, with only three values which can be used for comparison, namely 12, 70 and 200 ppm.

Antimony :
XRF data are to be preferred in this case. Maybe $SbF3$ is volatile or Sb precipitates in an acid solution.

Scandium :
The range of values for only eleven samples with XRF is < 2 to 19 ppm, with only two values which can be used for comparison, namely 7 and 19 ppm. The range of concentration is not very favourable for XRF.

Tin :
The range of values for only eleven samples with XRF is < 2 to 4 ppm, with no value which can sensibly be used for comparison. The range of concentration is not very favourable for XRF.

Strontium :
XRF data are to be preferred where "major" concentrations are present (as in this case). ICP-MS to be preferred when present in trace concentrations.

Tantalum :
Comments as for several elements above. A difficult range of concentrations.

Thorium :
The range of values for only eleven samples with XRF is < 5 to 12 ppm, with only two values which can be used for comparison. Th sometimes occurs in zirconium minerals, see above under zirconium. XRF values are to be preferred above 12 ppm Th.

Titanium :
XRF values are to be preferred.

Arsenic :
The range of values for only eleven samples with XRF is < 2 to 13 ppm, , with only one value which can be used for comparison

Barium :
XRF values are to be preferred well above the detection limit. Otherwise, for trace quantities, use ICP-MS results.

Bismuth :
The range of values for only eleven samples with XRF is < 3 to 8 ppm, , with no values which can sensibly be used for comparison

Cerium :
The range of values for only eleven samples with XRF is < 25 to 96 ppm, , with only two values which can be used for comparison. Ce sometimes occurs in zirconium minerals, see above under zirconium. Prefer XRF values for concentrations above 40 ppm Ce.

Cobalt :
The range of values for only eleven samples with XRF is < 3 to 18 ppm, with only two values which can be used for comparison

Chromium :
The range of values for only eleven samples with XRF is < 3 to 70 ppm, with only two (or three) values which can be used for comparison

Caesium :
The range of values for only eleven samples with XRF is < 5 to 13 ppm, , with only one value which can be used for comparison

Copper :
The range of values for only eleven samples with XRF is < 10 to 36 ppm. XRF values should be preferred for concentrations above 20 ppm Cu. AAS analysis should ideally be taken as a control.

Gallium :
The range of values for only eleven samples with XRF is < 3 to 22 ppm, with only two values which can be used for comparison

Hafnium :

The range of values for only eleven samples with XRF is < 5 to 6 ppm, , with no values which can sensibly be used for comparison

Lanthanum :
The range of values for only eleven samples with XRF is < 25 to 60 ppm, with only one-three values which can be used for comparison. La is sometimes situated together with Ce in zirconium minerals, see above under zirconium. XRF values are to be preferred at concentrations above 40 ppm La.

Manganese :
XRF data are to be preferred where values are well above the detection limit. ICP-MS to be preferred when present in trace concentrations.

(ii) Sample list

Bockfjord - Solid Samples: Preparation for ICPMS/XRF analysis

Prosjekt: 2717.00

Sv1R - several fragments of fine-grained grey marble, from outcrop in stream bed 1/3 of way between area 6 and moraine. Troll springs.

Sv2R - several fragments of fine-grained buff-yellow marble, from outcrop in stream bed 1/3 of way between area 6 and moraine. Troll springs.

Sv3R - several flakes of recently deposited travertine from the run-off surface of the travertine dome around spring 5A4, sample taken from within c. 2 m of spring outlet. Troll springs.

Sv4R - secondary carbonate (?) mineralisation in the breccia outcrop near area 6 (see Sv6) Troll springs.

Sv5R -brecciated and Qz-veined fine grained buff/yellow marble/dolomite, from outcrop area, near spring area 6. Troll springs.

Sv6R - heavily brecciated and mineralised fine-grained grey marble, from outcrop area, near spring area 6. Troll springs.

Sv7R - fragment of travertine from in-situ, topmost area 6 (RS has parallel sample). Troll springs.

Sv8R - fragment of in-situ travertine from fossil travertine basins below active springs in area 6. The travertine fragment is from a horizontal bed, ca. 40 cm from the uppermost surface of the travertine basin. Troll springs.

Sv9R - travertine basin bottom sediment from near core area in basin 2A4. Troll springs.

Sv10R - fragment of deep red/brown travertine. Loose block from lowermost part of area 1's travertine basin complex. Troll springs.

Sv11R - 2 fragments of travertine from a block fallen from «The Wall» (area 3), showing open and dense travertine layers. Troll springs.

Sv12R - large fragment of travertine breccia/conglomerate from south of area 1, down towards river level. Troll springs.

Sv13R - fragment of brecciated and Qz veined fine-grained buff/yellow marble/dolomite breccia from exposure scar behind spring area 3. Troll springs.

Sv14R - two fragments of travertine from top of area 7 (RS has similar samples). Troll springs.

Sv15R - samples of travertine from top of basin rim around basin 3A2 (RS has parallel sample). Troll springs.

Sv16R - two loose fragments of copper mineralisation found as loose fragments in solifuxion or weathering deposits. Troll springs.

Sv17R - large fragment of coarse grained marble. Loose block adjacent to marble outcrop below and slightly W of Jotunkilde 2. Shows solution features. (MH has other half of block). Jotun springs.

Sv18R - loose block of travertine breccia found near base of travertine scree below Jotunkilde 2.

Sv19R - fragment of mica schist thrown up in solifuxion furrow immediately above Jotunkilde 1

Sv20R - fragment of mica schist thrown up in solifuxion furrow immediately above Jotunkilde 1 (MH has parallel sample).

Sv21R - fragment of green (presumed Tertiary) sandstone in scree/minetip below mine entrance tunnel, higher mine tip, Mine 3, Bjørndalen, Longyearbyen

Sv22R - fragments of (possibly somewhat weathered) coal in minetip below mine entrance tunnel, higher mine tip, Mine 3, Bjørndalen, Longyearbyen

Sv23R - fragment of shale with yellow (iron sulphate ?) deposit on cleavage surfaces, lower tip area, Mine 3, Bjørndalen, Longyearbyen.

Sv24R - fragments ditto

Sv25R - loose sandstone/conglomerate core from old drilling site near base of Bjørndalen valley, higher up valley from mine tips. Longyearbyen.
Sv26R - fragments of (possibly somewhat weathered) coal in minetip above Sverdrupbyen (Mine 1, new mine), Longyearbyen.
Sv27R - fragments of fresh coal from coal face, Mine 3, tourist stross (Longyear Coal). Longyearbyen.
Sv28R - Devonian Old Red Sandstone, Trollkildene. Collected by Michael Heim.

Samples Sv21R to 27R are samples collected from the mining area in Longyearbyen and have no relevance to this project.

Sv 11R: The sample is a layered travertine with two main types of layer:

a: dense, crystalline travertine
b: open porous travertine

Two subsamples were prepared from sample Sv11R (one from each type of layer) and marked Sv11Ra and Sv11Rb.

Prøveforberedelsen

Prøvene, unntatt Sv19R og Sv28R er kalkstein av forskjellige typer.

Prøvene ønskes møllet til pulver i agatmølle. Minst 1 g homogenisert pulver legges i en liten plastflaske som skal sendes til Tyskland for ICPMS analyse.

Ved forberedelsen av prøvene, skal det i størst mulig grad unngås unødvendig kontakt med metall- eller andre potensielt forurensende gjenstander.

Spesielle betingelser:

Alle prøver: støv, fremmed jord og tilvekst av algae (spesielt **Sv15R**) skal fjernes ved vasking i destillert vann før pulverisering. I størst mulig grad skal det taes den ferskeste delen av prøven til pulverisering. Dette vil være vanskelig i flere tilfeller siden travertinene er tildels fossile og dermed forvitrede.

(iii) XRF analyses - Germany

	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O*
	%	%	%	%	%	%	%	%	%*
SV 1 R	1.81	0.069	0.97	0.46	0.032	0.74	52.41	0.13	0.26*
SV 3 R	3.02	0.010	0.09	0.05	0.005	0.84	50.91	0.11	0.03*
SV 5 R	9.77	0.011	<0.05	0.68	0.046	17.99	29.27	0.01	0.01*
SV 10 R	2.06	0.023	0.43	0.86	0.018	1.13	51.77	0.13	0.10*
SV 11 Ra	0.14	0.006	<0.05	0.07	0.010	0.67	54.23	0.09	0.01*
SV 11 Rb	0.19	0.004	<0.05	0.05	0.007	1.01	53.79	0.10	<0.01*
SV 14 R	0.98	0.023	0.33	0.34	0.064	0.77	53.43	0.05	0.05*
SV 15 R	1.11	0.007	<0.05	0.15	0.021	0.55	52.58	0.20	0.02*
SV 17 R	2.80	0.046	0.71	0.36	0.021	0.75	52.62	0.29	0.07*
SV 19 R	61.89	1.088	16.30	7.53	0.088	2.13	1.79	2.37	4.71*
SV 28 R	80.36	0.577	6.44	2.80	0.063	0.87	2.05	0.34	1.51*
	P2O5	(SO3)	(Cl)	(F)	LOI	Summe	(As)	Ba	Bi*
	%	%	%	%	%	%	ppm	ppm	ppm*
SV 1 R	0.022	0.83	0.011	<0.020	41.92	99.66	<2	54	<3*
SV 3 R	0.009	1.19	0.003	0.310	43.29	99.87	<2	230	<3*
SV 5 R	0.015	0.89	0.036	0.045	41.10	99.87	<2	33	8*
SV 10 R	0.018	1.08	0.031	0.168	42.02	99.84	<2	179	4*
SV 11 Ra	0.008	0.94	0.005	0.217	43.47	99.87	<2	196	<3*
SV 11 Rb	0.009	0.96	0.006	0.161	43.59	99.88	<2	161	5*
SV 14 R	0.025	1.05	0.017	0.048	42.65	99.83	13	107	<3*
SV 15 R	0.013	1.33	0.014	0.239	43.60	99.83	<2	194	7*
SV 17 R	0.031	0.97	0.015	0.073	41.17	99.93	<2	23	5*
SV 19 R	0.111	0.06	0.049	<0.020	1.53	99.65	3	922	4*
SV 28 R	0.146	0.67	0.011	<0.020	3.96	99.80	<2	271	<3*
	Ce	Co	Cr	Cs	Cu	Ga	Hf	La	Mo*
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm*
SV 1 R	<25	<3	5	6	18	<3	<5	<25	9*
SV 3 R	<25	<3	6	<5	11	<3	<5	<25	14*
SV 5 R	<25	<3	5	<5	12	<3	<5	<25	3*
SV 10 R	<25	<3	<3	<5	11	<3	<5	38	13*
SV 11 Ra	<25	<3	<3	<5	22	<3	<5	<25	17*
SV 11 Rb	<25	<3	<3	<5	36	<3	<5	<25	12*
SV 14 R	<25	7	8	<5	17	<3	<5	<25	16*
SV 15 R	<25	<3	4	6	21	<3	<5	<25	7*
SV 17 R	26	<3	9	<5	<10	<3	<5	<25	7*
SV 19 R	96	18	70	13	21	22	<5	60	3*
SV 28 R	86	8	41	5	16	9	6	39	<2*

Brackets ( ) indicate elements for which the method is not particularly suited and the results are subject to a greater degree of uncertainty.

Loss on ignition (LOI) is measured at temperatures which may partially or totally remove CO_2 from carbonates. LOI thus includes loss of CO_2, bound H_2O, some sulphur and organic carbon. LOI is taken as part of the sum (summe).

	Nb ppm	Ni ppm	Pb ppm	Rb ppm	Sb ppm	Sc ppm	Sn ppm	Sr ppm	Ta* ppm*
SV 1 R	<2	<3	<4	12	35	<2	<2	1861	<5*
SV 3 R	6	<3	<4	<2	22	3	<2	1232	<5*
SV 5 R	<2	<3	5	3	22	<2	<2	109	<5*
SV 10 R	4	<3	<4	3	6	3	<2	980	6*
SV 11 Ra	4	<3	<4	<2	15	3	<2	1090	<5*
SV 11 Rb	2	<3	<4	<2	28	3	<2	924	<5*
SV 14 R	6	<3	10	5	10	<2	<2	589	<5*
SV 15 R	7	<3	<4	<2	9	6	<2	880	<5*
SV 17 R	3	<3	<4	4	18	2	<2	174	<5*
SV 19 R	23	36	21	200	5	19	<2	227	<5*
SV 28 R	9	8	<4	70	7	7	4	39	<5*

	Th ppm	U ppm	V ppm	W ppm	Y ppm	Zn ppm	Zr ppm	* *
SV 1 R	<5	4	<5	<3	6	9	36	*
SV 3 R	<5	<3	<5	6	<3	18	16	*
SV 5 R	<5	5	9	8	4	16	<3	*
SV 10 R	<5	<3	12	6	7	10	26	*
SV 11 Ra	<5	4	11	14	<3	9	13	*
SV 11 Rb	<5	6	<5	4	<3	9	12	*
SV 14 R	<5	3	6	3	11	49	9	*
SV 15 R	<5	4	<5	5	5	14	12	*
SV 17 R	<5	4	6	10	5	11	7	*
SV 19 R	12	5	101	4	50	112	227	*
SV 28 R	12	4	33	<3	32	16	256	*

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SAMPLE PREPARATION and ANALYSIS of ROCKS, ORE MINERALS, SOILS and STREAM SEDIMENTS by XRF

The samples were milled to less than 40 5m particle size. 1000 mg were heated to 1030 0C for 15 min to determine loss on ignition (LOI). After mixing the residue with 5.0 g lithiummetaborate and 100 mg iodine pentoxide, it was fused at 1150 0C for 20 min for the rapid production of glasslike analytical disks with a good precision. It comprised the use of Pt-Au crucibles and a commercial automatic fluxer.

The advantages of fusion techniques are widely acknowledged to achieve homogeneous elemental distribution in glass disks and to reduce matrix effects (Tvrvk & van Grieken 1992, Tvrvk et al. 1996).

For quantitative analysis a wavelength-dispersive X-ray spectrometer (WDXRF) was used. For the determinations of TiO_2, CaO, K_2O and for the traces of Ba, Cs, Sb, Sc and Sn a Chromium-tube was used (PW 1480), for the determinations of As, Bi, Ce, Co, Cr, Cu, Ga, Hf, La, Mo, Nb, Ni, Pb, Rb, Sr, Ta, Th, U, V, W, Y, Zn and Zr and for SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O and P_2O_5 a Rhodium-tube (PW 2400).

Monitor samples and more than 50 certified reference materials (CRM) were used in the correction procedures. Matrix corrections were done according to □(>

Literature :

Tvrvk, S.B. & van Grieken, R.E. (1992): X-ray Spectrometry.- Anal. Chem., 64: 180 R - 196 R.

Tvrvk, S.B., Labar, J., Injuk, J. & van Grieken, R.E. (1996): X-ray Spectrometry. Anal. Chem., 68: 467 R - 485 R.

(iv) ICP-MS analyses on rock digests - Germany

	1	2	3	4	5	6	7	8*
identification	Ag	As	B	Ba	Be	Bi	Cd	Ce*
SV 1 R	0.027	1.65	2.36	44.3	0.30	.063	0.066	5.92*
SV 3 R	0.035	1.21	5.04	160	2.58	0.13	0.075	1.40*
SV 5 R	0.028	1.05	4.16	21.4	2.46	.034	0.073	2.66*
SV 10 R	0.020	1.91	6.83	168	6.10	.063	0.044	2.88*
SV 11 Ra	-.010	1.58	4.51	162	1.39	.020	0.035	0.083*
SV 11 Rb	-.010	1.37	5.14	145	1.57	.035	0.046	0.078*
SV 14 R	0.020	18.6	4.32	100	4.53	.050	0.44	3.48*
SV 15 R	-.010	1.18	6.91	185	3.60	.047	0.041	0.92*
SV 17 R	-.010	1.35	7.05	12.2	0.21	.077	0.052	4.91*
SV 19 R	0.11	1.29	8.71	879	2.36	0.13	0.089	94.5*
SV 28 R	0.048	1.32	47.4	270	1.85	.096	0.074	76.2*
identification	Ag	As	B	Ba	Be	Bi	Cd	Ce*

	9	10	11	12	13	14	15	16 *
	Co	Cr	Cs	Cu	Ga	Ge	Hf	(Hg)*
SV 1 R	0.046	7.45	0.44	11.4	1.38	0.073	0.36	0.035*
SV 3 R	0.74	7.61	0.58	7.46	0.41	4.07	0.10	-.010*
SV 5 R	1.64	7.41	0.048	5.98	0.38	0.13	0.043	0.016*
SV 10 R	2.03	5.58	1.33	4.02	0.89	1.22	0.27	0.019*
SV 11 Ra	1.50	2.21	0.061	1.53	0.31	0.20	-.010	0.015*
SV 11 Rb	1.92	3.80	0.15	3.70	0.53	0.51	-.010	0.016*
SV 14 R	2.13	5.28	2.50	8.58	0.88	0.53	0.053	0.012*
SV 15 R	1.98	4.28	0.42	6.27	0.40	2.86	0.061	0.014*
SV 17 R	2.18	6.40	0.29	3.22	1.22	0.14	0.22	-.010*
SV 19 R	20.5	81.3	15.6	25.4	25.0	0.80	5.33	0.034*
SV 28 R	7.74	47.2	6.26	4.90	8.99	0.10	4.47	0.035*
	Co	Cr	Cs	Cu	Ga	Ge	Hf	(Hg)*

	17	18	19	20	21	22	23	24*
	In	La	Li	Mn	Mo	Nb	Ni	Pb*
SV 1 R	0.005	2.94	1.53	201	0.14	1.16	3.82	4.06*
SV 3 R	-.005	0.66	7.40	11.7	0.17	0.15	2.60	2.53*
SV 5 R	0.007	1.20	4.45	378	0.22	0.14	2.46	8.02*
SV 10 R	-.005	1.36	7.28	139	0.097	0.55	3.00	1.36*
SV 11 Ra	-.005	0.034	3.03	67.1	0.058	0.033	2.67	-1.00*
SV 11 Rb	-.005	0.039	5.66	56.5	0.041	0.041	2.07	-1.00*
SV 14 R	-.005	2.59	2.77	607	0.094	0.52	3.54	10.9*
SV 15 R	-.005	0.45	6.52	180	0.057	0.11	3.09	1.28*
SV 17 R	0.006	2.65	2.59	199	0.055	0.83	3.90	3.26*
SV 19 R	0.085	45.0	63.9	900	0.30	22.7	36.7	25.7*
SV 28 R	0.032	34.6	18.6	621	0.15	11.1	15.3	3.70*

	25	26	27	28	29	30	31	32*
	(Rb)	Sb	Sc	Se	Sn	Sr	Ta	Th*
SV 1 R	22.0	0.12	1.30	0.26	5.74	1210	0.34	0.74*
SV 3 R	2.15	0.030	0.34	0.61	2.20	793	0.10	0.31*
SV 5 R	0.62	0.27	0.48	1.39	1.88	125	0.097	0.15*
SV 10 R	8.95	0.047	1.08	0.11	1.85	1270	0.13	0.58*
SV 11 Ra	0.52	0.018	0.25	-.100	1.65	1070	0.056	0.015*
SV 11 Rb	0.51	0.014	0.35	0.13	1.50	959	0.066	0.019*
SV 14 R	6.41	0.17	1.32	0.22	1.69	665	0.11	0.40*
SV 15 R	2.02	0.032	0.73	0.14	2.01	1150	0.072	0.13*
SV 17 R	3.83	0.018	1.33	0.10	1.85	211	0.11	0.57*
SV 19 R	233	0.040	19.6	0.60	5.35	254	1.49	15.9*
SV 28 R	87.7	0.36	6.91	0.53	3.79	52.9	0.92	12.1*

```
                  33      34      35      36      37      38      39     40 *
                 (Ti)     Tl      U       V       W       Y       Zn    (Zr)*
SV 1 R            328   0.087    0.72    3.78    1.08    5.18    6.27   12.8*
SV 3 R           24.7   0.013    0.29    1.69    0.28    0.84    10.9   3.86*
SV 5 R           45.9   0.015    0.11    2.77    0.31    3.08    12.6   1.79*
SV 10 R           142   -.005    0.31    2.57    0.63    2.20    5.92   10.8*
SV 11 Ra         4.32   0.024    0.30    2.46    0.12    0.30    1.88   0.20*
SV 11 Rb         6.26   0.017    0.30    3.72    0.15    0.43    3.11   0.35*
SV 14 R           170   0.026    0.40    2.43    0.72    9.76    46.4   2.27*
SV 15 R          35.7   0.021    0.44    3.10    0.45    2.83    7.11   2.17*
SV 17 R           395   0.018    0.11    2.57    0.13    2.87    4.93   8.27*
SV 19 R          9810    0.71    3.35     114    1.96    17.8     135    197*
SV 28 R          5050    0.26    2.34    40.6    1.26    26.5    22.5    164*
-----------------------------------------------------------------------------*
                  41      42      43      44      45      46      47      48*
                  Pr      Nd      Sm      Eu      Gd      Tb      Dy      Ho*
SV 1 R           0.75    3.01    0.62    0.11    0.66   0.099    0.63   0.13*
SV 3 R           0.16    0.58    0.11   0.005    0.11   0.016   0.085  0.019*
SV 5 R           0.36    1.58    0.40    0.11    0.45   0.067    0.40  0.078*
SV 10 R          0.34    1.32    0.28   0.037    0.27   0.043    0.28  0.059*
SV 11 Ra        0.011   0.047   0.011   0.008   0.016   0.004   0.029  0.008*
SV 11 Rb        0.010   0.062   0.011   0.008   0.023   0.004   0.034  0.009*
SV 14 R          0.58    2.47    0.56    0.12    0.71    0.13    0.91   0.20*
SV 15 R          0.12    0.51    0.12   0.015    0.16   0.034    0.24  0.062*
SV 17 R          0.59    2.18    0.42    0.10    0.41   0.061    0.39  0.077*
SV 19 R          11.3    42.9    8.05    1.48    6.74    0.87    4.12   0.66*
SV 28 R          8.62    32.4    6.20    1.04    5.87    0.87    4.86   0.92*
-----------------------------------------------------------------------------*
                  49      50      51      52*                                *
                  Er      Tm      Yb      Lu*                                *
SV 1 R           0.39   0.054    0.32  0.056*                                *
SV 3 R          0.064   0.009   0.063  0.013*                                *
SV 5 R           0.21   0.029    0.18  0.028*                                *
SV 10 R          0.17   0.026    0.18  0.029*                                *
SV 11 Ra        0.017   0.003   0.024  0.005*                                *
SV 11 Rb        0.027   0.003   0.029  0.006*                                *
SV 14 R          0.59   0.087    0.56  0.092*                                *
SV 15 R          0.19   0.030    0.18  0.034*                                *
SV 17 R          0.22   0.035    0.21  0.037*                                *
SV 19 R          1.65    0.22    1.40   0.23*                                *
SV 28 R          2.58    0.37    2.48   0.39*                                *
---------------------------------------*                                     *

 "Feb" 7 1997
 "QUANTITATIVE ANALYSIS: DATA SET SUMMARY"
 "Gesteine, Svalbard/Norwegen"
  100.0 mg + 5.0 ml HNO3 + 2.0 ml HF (24 hrs at 170 0C) to dryness,
           + 3.0 ml HCl              (12 hrs at 150 0C),
           + 1.0 ml HNO3 + 1.0 ml HCl to 100.0 g (dilution factor = 1000.)
```

All results in ppm.
The minus sign signifies less than detection limit. -0.002 means <0.002
Brackets ( ) indicate elements for which the method is not particularly suited and the results are subject to a greater degree of uncertainty. This may be due to (a) high concentrations and out of range for a trace-element instrument, (b) low sensitivity to plasma excitation (counts per second per ppb/ppm) or (c) interferences.

Appendix 6

XRD analysis of rocks by NGU

NGU
Norges geologiske undersøkelse

Postboks 3006 - Lade
7002 TRONDHEIM
Tlf.: 73 90 40 11
Telefaks: 73 92 16 20

ANALYSERAPPORT

NORSK
AKKREDITERING
Nr. P020

ANALYSEKONTRAKT NR.: 1997.0043
NGU PROSJEKT NR.: 2717.00

OPPDRAGSGIVER: NGU, Varme kilder Svalbard

ADRESSE:

TLF.: 310

KONTAKTPERSON: David Banks

PRØVETYPE: Bergart
ANTALL PRØVER: 3
IDENTIFIKASJON AV PRØVER: Iflg. liste fra oppdragsgiver
PRØVER MOTTATT: 13.02.97
ANMERKNINGER: Ingen

SPESIFIKASJON AV OPPDRAGET I HENHOLD TIL ANALYSEKONTRAKT:

METODE	DOKUMENTASJON *)	OMFATTES AV AKKREDITERING
XRD	NGU-SD 4.1	Ja

Denne rapporten inneholder i alt 5 sider + 3 vedlegg. Rapporten må ikke gjengis i utdrag uten skriftlig godkjenning fra NGU-Lab.

Alle forhold ved prøvetaking, behandling og transport av prøvene før innlevering til NGU-Lab er underlagt oppdragsgivers ansvar. Analyseresultater framlagt i denne rapporten refererer derfor kun til det prøvematerialet som er mottatt av NGU-Lab.

Trondheim, 17. februar 1997

Magne Ødegård (e.f.)

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*) Fortegnelse over dokumentasjon finnes i NGU-Labs Kvalitetshåndbok, NGU-SD 0.1, som kan rekvireres fra NGU-Labs sekretariat.

NGU
Norges geologiske undersøkelse

Postboks 3006 - Lade
7002 TRONDHEIM
Tlf.: 73 90 40 11
Telefaks: 73 92 16 20

XRD-ANALYSER (Kvalitativ mineralbestemmelse)
Analysekontraktsnr: 1997.0043

NORSK AKKREDITERING
Nr. P020

PROSJEKTNR.: 2717.00 **OPPDRAGSGIVER: David Banks**

PRØVEART: Bergart/mineral **ANTALL PRØVER:** 3

MOTTATT: 13.02.97

BEHANDLINGSMETODE: XRD-opptak , scan 3-70°2θ , scan speed 0.02 °2θ/s

ARBEIDET UTFØRT AV: Andreas Grimstvedt

ANTALL SIDER: 3+3 vedlegg (3 stk. XRD-opptak for hver prøve med peak search og software basert identifisering-scorelist)

PRESISJON : Det kjøres rutinemessig kontrollprøver (2θ-verdi/d-verdi), som føres i kontrolldiagram (X-diagram). Disse kan forevises om ønskelig.

ANMERKNINGER: Se de påfølgende sider

Rapporten må ikke gjengis i utdrag uten skriftlig godkjenning fra NGU-Lab.

Andreas Grimstvedt

Ferdig analysert	17.februar.1997	Andreas Grimstvedt
	Dato	OPERATØR

KOMMENTARER TIL XRD-ANALYSE

For hver prøve følger det med utskrift av diffraktogramet hvor beregnede topper er innsatt som vertikale linjer (peak search). I tillegg resultat fra software basert identifisering ("score list"), denne inkluderer et diffraktogram hvor topper for utvalgte mineraler er innsatt.

PEAK SEARCH

Tabell med posisjonen (2θ-verdi med tilhørende d-verdi) og høyden (intensitet) på beregnede topper. Videre kolonne med relative intensiteter (i forhold til høyeste topp)

IDENTIFISERING

Som et hjelpemiddel for identifisering er de beregnede toppene benyttet i søk i database (JCPDS). Hovedprinsippet for søket er bestemmelse av antall topper i de ulike datakort som passer med topper i opptaket. Resultatet av et slikt søk er listet i en "score list".

Forklaring til "score list"

Match score :	Antall topper for det aktuelle mineral som passer med topper i opptaket
Rel score :	Fraksjon av topper for det aktuelle mineral som passer med opptaket, dvs. Match score/tot. antall topper(på datakortet) for mineralet
Card-Id :	Kortnr. for det aktuelle mineral i JCPDS-databasen

NB! Navn på de listede mineraler er gitt på påfølgende side (sidenr. indeksert med .1) i samme rekkefølge.

Forslag (innsatte) mineraler er merket med * i kolonne 2.

I tillegg til "score listen" følger det med diffraktogrammet hvor toppene til utvalgte mineraler er innsatt (vertikale linjer). Under dette diffraktogramet er det rubrikker med posisjon for topper. Den første rubrikken innholder toppene til det aktuelle opptaket, mens de resterende er toppene på de innsatte mineralene (de samme som er merket med * i "score list").

P.g.a. at en del mineraler har overlappende linjer behøver ikke alle forslagene å være tilstede i prøvene. Ta gjerne kontakt dersom mer informasjon om de vedlagte "score listene" ønskes.

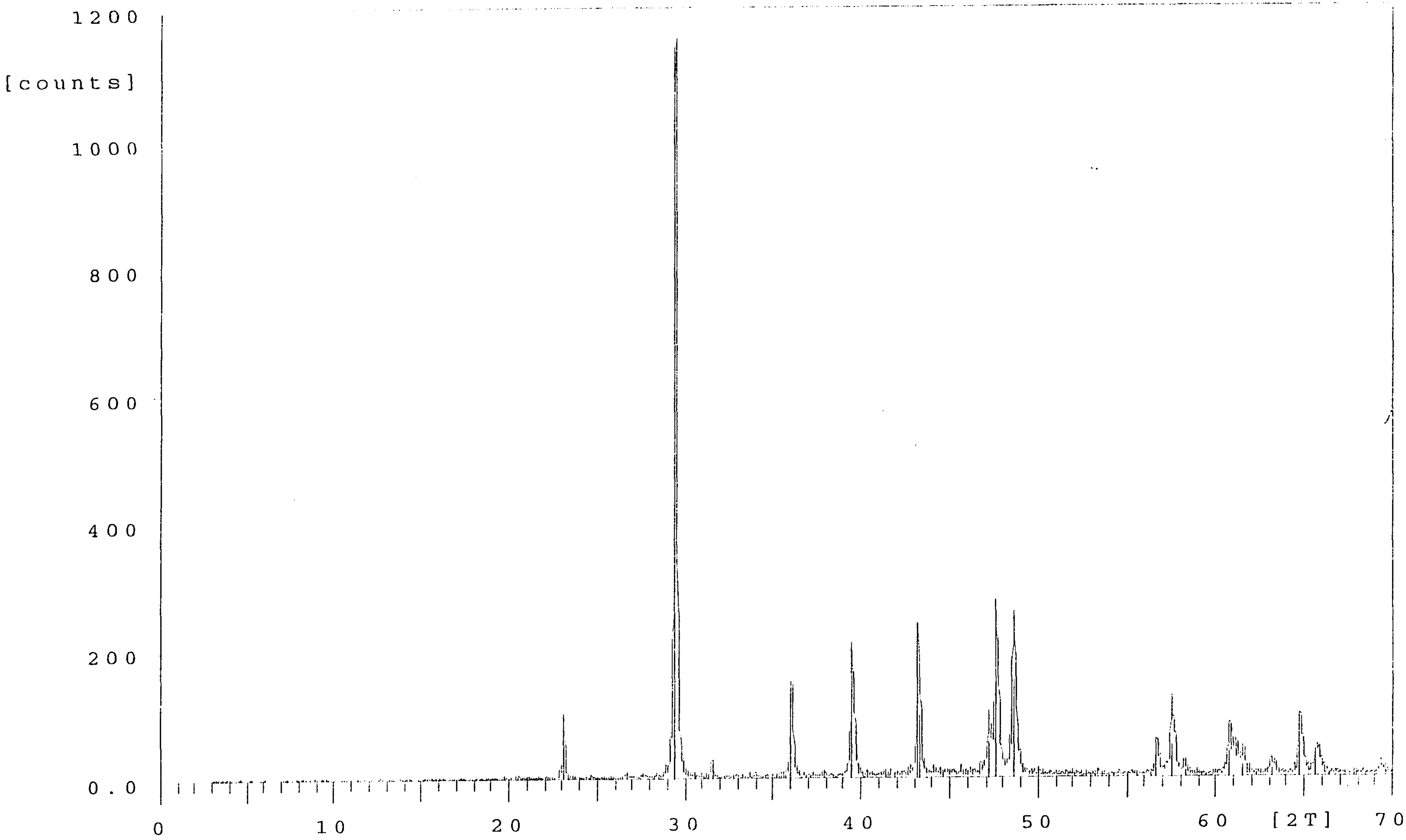
XRD-ANALYSER (Kvalitativ mineralbestemmelse)

Analysekontraktsnr: 1997.0043

Tabell 1 Veiledende oppsummering av identifisering mineraler. Se vedlagte scorelister for flere detaljer.

Prøve merket	Filnavn	Hoved mineral	Andre mulige mineraler	Merknader
Sv3R	DB01.sd	Calcitt	*Kvarts, monohydrat*	*Andre mulige mineraler foreligger i relativt sett små mengder. Tilstedeværelsen av disse er således usikker, og således er det mulig at andre enn de foreslåtte kan inngå.*
Sv10R	DB02.sd	Calcitt	*Glimmer(eks.zinwalditt)*	*Andre mulige mineraler foreligger i relativt sett små mengder. Tilstedeværelsen av disse er således usikker, og således er det mulig at andre enn de foreslåtte kan inngå.*
Sv15R	DB03.sd	Calcitt		

Sample identification Sv3R 14-feb-1997 14:11



DB01.SD DB01.DI

Sv3R

[redacted]

[illegible]

```
File: C:\ANN\DATA\DB01.DI                                          14-feb-1997 14
==================================================================================
NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********

P E A K   S E A R C H:

            Input file: DB01.SD

       Start angle [°2θ]: 3.010
         End angle [°2θ]: 69.990
    Maximum d-value  [Å]: 29.32891
    Minimum d-value  [Å]: 1.34314
Maximum number of counts: 338

   Sample identification: Sv3R

          Anode material: Cu
      α1 Wavelength  [Å]: 1.54060
      α2 Wavelength  [Å]: 1.54439

Intensity measured with FIXED slit

P E A K  S E A R C H:

 d-value     Angle Tip width   Height   Background   Rel. int.  Significanc
   [Å]       [°2θ]   [°2θ]    [counts]   [counts]       [%]
 --------   ------- ---------  -------  ----------  ---------  -----------
 6.18662    14.305    0.240        3           1         0.3         1.09
 4.33518    20.470    0.160        6           2         0.5         0.82
 3.84311    23.125    0.080      100           2         8.8         1.10
 3.33671    26.695    0.160        8           3         0.7         0.88
 3.02952    29.460    0.120     1142           3       100.0         9.64
 2.83519    31.530    0.160       24           4         2.1         1.56
 2.49074    36.030    0.100      123           4        10.8         2.51
 2.28122    39.470    0.080      154           6        13.5         1.48
 2.09135    43.225    0.080      151           8        13.2         2.05
 2.08538    43.355    0.060       90           8         7.9         0.79
 1.92484    47.180    0.080       49           9         4.3         1.29
 1.90921    47.590    0.080      169           8        14.8         1.12
 1.87150    48.610    0.080      149           8        13.0         0.91
 1.82132    50.040    0.160        4           7         0.3         0.89
 1.62336    56.655    0.100       30           5         2.6         1.27
 1.60264    57.455    0.100       49           5         4.3         1.38
 1.58277    58.245    0.200        6           5         0.5         0.83
 1.52359    60.740    0.160       36           5         3.2         1.74
 1.50580    61.535    0.160       15           5         1.3         0.82
 1.47196    63.110    0.120       10           5         0.9         1.01
 1.43818    64.770    0.080       45           6         3.9         1.44
 1.42073    65.665    0.240       18           6         1.5         2.16
 1.37940    67.895    0.040        4           6         0.4         0.84

==================================================================================
                                        1
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[illegible]

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File: C:\ANN\DATA\DB01.IDN                                         14-feb-1997 14
==================================================================================
NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********

S C O R E   L I S T   L O N G:

Analysed DI file                   : C:\ANN\DATA\DB01.DI
Sample identification              : Sv3R
Last update of results file        : 14-feb-1997 14:31

Database used                      : C:\IDENTDB

MEASUREMENT PARAMETERS

Diffractometer                     : X'PERT
Start angle                        : 3.010
Final angle                        : 69.990
Step size                          : 0.020
Time per step                      : 1.0
Anode material                     : Cu
Focus                              : LFF

Date and time of measurement       : 14-feb-1997 10:16

PEAK SEARCH PARAMETERS

Minimum peak width                 : 0.00
Maximum peak width                 : 1.00
Peak base width                    : 2.00
Minimum significance               : 0.75

Number of peaks detected           : 23

SEARCH-MATCH PARAMETERS

Number of strong lines of the
reference patterns used in SEARCH  : 5
Intensity threshold                : 3.02
Confidence threshold               : 10
Minimum specimen displacement      : -100
Maximum specimem displacement      : 100
Step size in specimen displacement: 25

Restrictions file      : MINERAL

Results:

+---+-+---------+-+------+------+------+------+----+-----+------------------+
|   |I|Card Id |#|Search|Search| Match|Rel m|Conc|Displ|Formulas          |
|   | |         | | score| displ| score|score |    |     |                  |
+---+-+---------+-+------+------+------+------+----+-----+------------------+
|  1|*|24-0027 |1|    98|    75| 14.14| 0.83|  48|   80| CaCO3            |
|  2|*|05-0586 |1|    96|   100| 16.29| 0.81|  58|  127| CaCO3            |
|  3| |06-0615 |1|    63|     0|  1.45| 0.48|   6|   16| FeO              |
|  4| |06-0680 |1|    42|  -100|  2.27| 0.45|   0|  -77| Cu2-xSe          |
+---+-+---------+-+------+------+------+------+----+-----+------------------+

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                                        1
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5.

1997.0045 vedlegg 1 [illegible]

```
File: C:\ANN\DATA\DB01.IDN                                        14-feb-1997 14
=================================================================================
NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********

+-----------------------------+
|Name                         |
|                             |
+-----------------------------+
|Calcite                      |
|Calcite, syn                 |
|W\PIustite, syn              |
|Berzelianite                 |
+-----------------------------+

=================================================================================
                                   1.1
```

1997.0045 vedlegg 1 [illegible]

```
File: C:\ANN\DATA\DB01.IDN                                        14-feb-1997 14
=================================================================================
NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********

+---+-+--------+-+------+------+------+-----+----+-----+---------------------+
|   |I|Card Id |#|Search|Search| Match|Rel m|Conc|Displ|Formulas             |
|   | |        | | score| displ| score|score|    |     |                     |
+---+-+--------+-+------+------+------+-----+----+-----+---------------------+
|  5| |18-0438 |1|    54|  100 |  2.13| 0.43|   0|  134| Cu1.4As0.9S2        |
|  6| |12-0646 |1|    54|    0 |  2.13| 0.43|   0|   16| Cu3(As,V)S4         |
|  7| |14-0567 |1|    40| -100 |  4.18| 0.42|   1|  -77| (Sn,Fe)(O,OH)2      |
|  8| |04-0835 |1|    50|   75 |  1.23| 0.41|   3|  109| NiO                 |
|  9| |04-0691 |1|    38|    0 |  4.08| 0.41|   0|   12| AgBiS2              |
| 10|*|33-1161 |1|    54|   25 |  7.26| 0.40|   1|   26| SiO2                |
| 11| |37-1492 |1|    50| -100 |  6.29| 0.39|   1| -110| MoS2                |
| 12| |34-0171 |1|    38|   50 |  8.16| 0.39|   1|   84| CuSe                |
| 13| |06-0097 |1|    46|  -75 |  5.39| 0.39|   1|  -76| MoS2                |
| 14| |26-1079 |1|    38|    0 |  2.27| 0.38|   1|   34| C                   |
| 15| |08-0012 |1|    42| -100 |  1.88| 0.38|   0|  -84| AgSb2(O,OH,H2O)6    |
| 16| |30-0093 |1|    54|    0 | 10.69| 0.37|   1|   34| Pd8Sb3              |
| 17| |38-0346 |1|    38|   25 |  2.93| 0.37|   0|   37| Ni18Bi3AsS16        |
| 18| |07-0007 |1|    42|  100 |  2.55| 0.36|   1|  110| NH4Cl               |
| 19| |07-0321 |1|    42|    0 |  2.18| 0.36|   0|   16| PbxSb2-z(O,OH,H2O)  |
| 20| |11-0121 |1|    38| -100 |  3.98| 0.36|   0|  -90| Co3S4               |
| 21| |27-0281 |1|    38|   25 | 11.61| 0.35|   1|   59| Pb2UO2(CO3)3        |
| 22| |18-0672 |1|    41|  -75 |  6.68| 0.35|   0|  -85| NaMnZn2(Ti,Fe)6Ti1  |
| 23| |35-0582 |1|    42|  100 |  4.90| 0.35|  13|  134| Cu2FeSnS4           |
| 24| |02-1231 |1|    63|  -25 |  1.40| 0.35|   6|  -26| CuZn                |
| 25| |08-0002 |1|    47| -100 | 11.12| 0.35|   1| -119| UTi2O6              |
| 26| |25-0597 |1|    38|  100 |  9.01| 0.35|   0|  105| Pd5Sb2              |
| 27| |17-0546 |1|    47|    0 | 11.33| 0.34|   3|   16| KCa4F(Si2O5)4!8H2O  |
| 28| |12-0688 |1|    50| -100 |  9.88| 0.34|   9|  -84| ZnS                 |
| 29| |39-1363 |1|    50| -100 |  9.88| 0.34|   9|  -84| ZnS                 |
| 30| |30-0991 |1|    44|  -75 |  5.09| 0.34|   0|  -56| (K,Sr)2-xNb2O6(O,O  |
| 31| |05-0418 |1|  5000|    0 | 13.19| 0.34|   1|  255| SrCO3               |
| 32| |43-1469 |1|    40|  100 |  3.72| 0.34|   0|  134| Ni3S4               |
| 33| |25-0298 |1|    42| -100 | 10.47| 0.34|   3| -130| Cu6Hg3As4S12        |
| 34| |18-0972 |1|    75|  -25 |  3.01| 0.33|   2|  -20| PtS                 |
| 35| |24-0334 |1|    41|   25 |  4.99| 0.33|   0|   59| CoNi2S4             |
| 36| |15-0445 |1|    46| -100 |  7.97| 0.33|   2|  -88| Fe-Mg-Al-SiO        |
| 37| |25-0264 |1|    46| -100 |  5.93| 0.33|   0|  -84| Cu6As4S9            |
| 38| |35-0581 |1|    38| -100 |  9.54| 0.33|   5|  -84| Cu3SbS4             |
| 39| |08-0237 |1|    38|  -25 |  5.54| 0.33|   0|  -37| WS2                 |
| 40| |29-0927 |1|    40|  -25 |  7.10| 0.32|   0|  -30| Ni9Sb2S8            |
| 41| |14-0603 |1|    39|   75 |  7.40| 0.32|   0|   94| NaNbO3              |
| 42| |16-0696 |1|    38|  100 |  6.05| 0.32|   1|   84| (Re,Ca,Fe)0.90NbTi  |
| 43| |35-0706 |1|    39|    0 |  5.69| 0.32|   0|   16| (Na,Cs)Bi(Ta,Nb,Sb  |
| 44| |29-0962 |1|    39| -100 | 11.68| 0.32|   1|  -99| Pd10As4Bi           |
| 45| |40-0492 |1|    38|    0 | 29.74| 0.31|   3|   10| AsTi3V4O13(OH)      |
| 46| |05-0739 |1|    38|  100 |  2.19| 0.31|   1|  119| MgSiO3!H2O          |
| 47| |29-0823 |1|    58| -100 | 10.55| 0.31|   1| -112| Na2KLi(Mn,Fe)2Ti2S  |
| 48| |04-0728 |1|    41|   25 |  5.56| 0.31|   1|   59| Ca3Mg(SiO4)2        |
| 49| |13-0114 |1|    49| -100 |  6.42| 0.31|   1|  -84| FeZn3Be3Si3O12S     |
| 50| |33-0876 |1|    38|  100 | 19.54| 0.31|   1|  123| Mg3(PO4)2           |
| 51| |11-0508 |1|    39|   25 | 11.53| 0.30|   0|   15| Pd17Se15            |
+---+-+--------+-+------+------+------+-----+----+-----+---------------------+

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                                    2
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Sv 3R

vii

1997.0045 Vedlegg 1

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File: C:\ANN\DATA\DB01.IDN                                     14-feb-1997 14
==============================================================================
NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********


+------------------------------+
|Name                          |
|                              |
+------------------------------+
|Sinnerite                     |
|Arsenosulvanite               |
|Cassiterite                   |
|Bunsenite, syn                |
|Matildite                     |
|Quartz, syn                   |
|Molybdenite-2\ITH\RG, syn     |
|Klockmannite, syn             |
|Molybdenite-2H, syn           |
|Graphite-3\ITR\RG, syn [NR]   |
|Stetefeldtite                 |
|Mertieite-II, syn             |
|Arsenohauchecornite           |
|Salammoniac, syn              |
|Bindheimite                   |
|Linnaeite                     |
|Widenmannite                  |
|Landauite                     |
|Stannite                      |
|Zhanghengite, syn             |
|Brannerite, heated            |
|Stibiopalladinite             |
|Fluorapophyllite              |
|Wurtzite-10\ITH\RG            |
|Wurtzite-8\ITH\RG             |
|Kalipyrochlore                |
|Strontianite, syn             |
|Polydymite                    |
|Aktashite                     |
|Cooperite, syn                |
|Siegenite, syn                |
|Unnamed mineral [NR]          |
|Sinnerite, syn                |
|Famatinite, syn               |
|Tungstenite-2\ITH\RG, syn     |
|Tucekite                      |
|Lueshite, syn                 |
|Aeschynite                    |
|Natrobistantite               |
|Palladobismutharsenide, syn   |
|Tomichite                     |
|Cerolite                      |
|Manganneptunite               |
|Merwinite, syn                |
|Genthelvite                   |
|Farringtonite, syn            |
|Palladseite, syn              |
+------------------------------+

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1997.0045 Vedlegg 1

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File: C:\ANN\DATA\DB01.IDN                                     14-feb-1997 14
==============================================================================
NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********


+---+-+-------+-+------+------+------+-----+----+-----+-------------------+
|   |I|Card Id|#|Search|Search| Match|Rel m|Conc|Displ|Formulas           |
|   | |       | | score| displ| score|score|    |     |                   |
+---+-+-------+-+------+------+------+-----+----+-----+-------------------+
| 52| |27-0250|1|    38|     0| 21.53| 0.30|   1|   34| Fe3(PO4)2         |
| 53| |42-0423|1|    38|    50| 12.42| 0.30|   3|   40| CaTiO3            |
| 54| |13-0550|1|    39|     0|  5.68| 0.30|   0|   16| Fe2Tl14O24        |
| 55| |35-0525|1|    44|   100|  4.48| 0.30|   0|  119| (Cu,Zn,Ag)12(As,Sb|
| 56| |19-0392|1|    42|   -50|  5.08| 0.30|   1|  -40| Cu2(WO4)(OH)2     |
| 57| |25-0279|1|    43|    50|  2.99| 0.30|   0|   80| CuGaS2            |
| 58| |35-1351|1|    38|   100|  5.94| 0.30|   6|  134| Cu2FeSnS4         |
| 59| |03-0503|1|    39|   100|  7.10| 0.30|   1|  110| 3NaAlSiO4!CaCO3   |
| 60| |15-0682|1|    52|   -75|  5.91| 0.30|   0|  -65| PbSeO4            |
| 61| |22-0349|1|    40|     0|  2.65| 0.29|   5|   23| (Fe,Mg)(Cr,Fe)2O4 |
| 62| |38-0430|1|    42|  -100|  2.94| 0.29|   1|  -66| MnFe2O4           |
| 63| |39-1469|1|    39|    75| 12.25| 0.29|   0|  109| Ba0.75Sr0.25SO4   |
| 64| |29-0808|1|    39|     0|  8.45| 0.29|   1|   10| Li1-x(Fe,Mn)PO4   |
| 65| |02-1257|1|    46|   -25|  2.91| 0.29|   0|  -20| CaCe2(CO3)3F2     |
| 66| |21-1276|1|    39|   -25|  3.48| 0.29|   3|  -20| TiO2              |
| 67| |42-1449|1|    41|    25|  3.47| 0.29|   1|   24| FeNi2S4           |
| 68| |22-1135|1|    50|   -50| 13.69| 0.29|   0|  -55| Pb2(SO4)(SeO4)    |
| 69|*|29-0306|1|    46|   -25| 10.24| 0.28|   0|  -20| CaCO3!H2O         |
| 70| |05-0283|1|    54|    50|  9.10| 0.28|   1|   62| CaAl(F,OH)5!H2O   |
| 71| |05-0417|1|    38|   -75|  9.66| 0.28|   2|  -74| PbCO3             |
| 72| |13-0583|1|    40|  -100|  6.24| 0.28|   1| -110| CaHAsO4!2H2O      |
| 73| |27-0034|1|    38|     0| 10.96| 0.28|   0|   27| BaCe2(CO3)3F2     |
| 74| |38-0478|1|    41|  -100|  5.01| 0.28|   1|  -70| Mg6Al2(OH)18!4H2O |
| 75| |08-0003|1|    55|  -100|  5.00| 0.28|   0|  -90| Pb5Au(Te,Sb)4Sx   |
| 76| |14-0345|1|    38|     0|  8.60| 0.28|   0|   34| Ce-La-Sr-Ca-C-O-H!|
| 77| |29-0384|1|    38|     0|  8.60| 0.28|   0|   34| (Sr,Ca)(La,Ce)(CO3|
| 78| |12-0277|1|    38|  -100|  3.88| 0.28|   0|  -84| (La,Y)PO4!H2O     |
| 79| |29-1420|1|    39|     0|  6.35| 0.28|   0|   34| Cu3PbTeO4(OH)6    |
| 80| |11-0312|1|    67|    25| 15.68| 0.27|   2|   15| (K,Na)Cu7AlSi9O24(|
| 81| |41-1498|1|    50|    50|  6.83| 0.27|   1|   80| (Cu10Hg2)Sb4S12   |
| 82| |05-0737|1|    39|    50|  5.12| 0.27|   0|   38| (Sr,Ca)Al3(PO4)(SO|
| 83| |21-0974|1|    57|  -100| 11.01| 0.27|   1|  -84| NiSO4!H2O         |
| 84| |28-2002|1|    38|   -25| 15.03| 0.27|   0|  -35| C6H4(CO)2C6H4     |
| 85| |12-0625|1|    39|     0| 10.70| 0.27|   0|   16| Mg2(Al,Fe)6(SiO4)4|
| 86| |39-0326|1|    47|   -50|  8.48| 0.27|   1|  -40| CuPb8(AsO3)2O3Cl5 |
| 87| |20-0240|1|    38|     0| 14.27| 0.26|   0|   12| Ca5(SiO4)2(OH)2   |
| 88| |27-0669|1|    39|   -50| 15.86| 0.26|   1|  -40| Na6(Ca,Mn)(Ti,Fe)S|
| 89| |41-1431|1|    39|   100|  6.34| 0.26|   1|  130| CaWO4             |
| 90| |37-0414|1|    38|  -100| 16.03| 0.26|   0| -105| Ca5(SiO4)2(OH,F)2 |
| 91| |29-0322|1|    39|   -75|  7.61| 0.26|   0|  -59| Ca2F2CO3          |
| 92| |31-0462|1|    46|   100|  5.50| 0.26|  11|  123| Cu4FeZnSn2S8      |
| 93| |33-0188|1|    43|     0| 18.65| 0.26|   1|   27| Ba4(V,Ti)4ClSi8B2O|
| 94| |30-0263|1|    39|    50| 12.65| 0.26|   0|   40| (Ca,Ce)(Ti,Fe,Cr,M|
| 95| |11-0491|1|    42|   100|  5.38| 0.26|   0|  116| (Fe,Mn)4Be3Si3O12S|
| 96| |24-0730|1|    43|    50|  8.70| 0.26|   1|   77| (Mn,Fe)AlPO4(OH,O)|
| 97| |26-0292|1|    38|  -100|  4.58| 0.25|   2|  -81| Ca3Al2(SiO4)3     |
| 98| |11-0695|1|    46|     0|  7.39| 0.25|   8|   16| SiO2              |
+---+-+-------+-+------+------+------+-----+----+-----+-------------------+

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Sv 3R

viii

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File: C:\ANN\DATA\DB01.IDN                             14-feb-1997 14
=========================================================================
NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********

 +------------------------------+
 |Name                          |
 |                              |
 +------------------------------+
 |Graftonite, syn               |
 |Perovskite, syn               |
 |Avicennite                    |
 |Giraudite                     |
 |Cuprotungstite, syn           |
 |Gallite, syn                  |
 |Stannite, syn                 |
 |Cancrinite                    |
 |Kerstenite, syn [NR]          |
 |Donathite                     |
 |Iwakiite                      |
 |Barite, strontian, syn        |
 |Ferrisicklerite               |
 |Parisite-(Ce)                 |
 |Rutile, syn                   |
 |Violarite                     |
 |Olsacherite                   |
 |Monohydrocalcite              |
 |Gearksutite                   |
 |Cerussite, syn                |
 |Pharmocolite                  |
 |Cordylite-(Ce)                |
 |Meixnerite                    |
 |Nagyagite, syn                |
 |Ancylite                      |
 |Ancylite-(Ce)                 |
 |Rhabdophane-(La)              |
 |Parakhinite                   |
 |Ajoite                        |
 |Tetrahedrite, mercurian, syn  |
 |Svanbergite, calcian          |
 |Dwornikite, syn               |
 |Hoelite, syn                  |
 |Yoderite                      |
 |Freedite                      |
 |Calcio-chondrodite, syn       |
 |Koashvite                     |
 |Scheelite, syn                |
 |Reinhardbraunsite, fluorian   |
 |Brenkite                      |
 |Stannite, syn                 |
 |Nagashimalite                 |
 |Loveringite                   |
 |Danalite                      |
 |Ernstite                      |
 |Grossular                     |
 |Cristobalite, syn             |
 +------------------------------+

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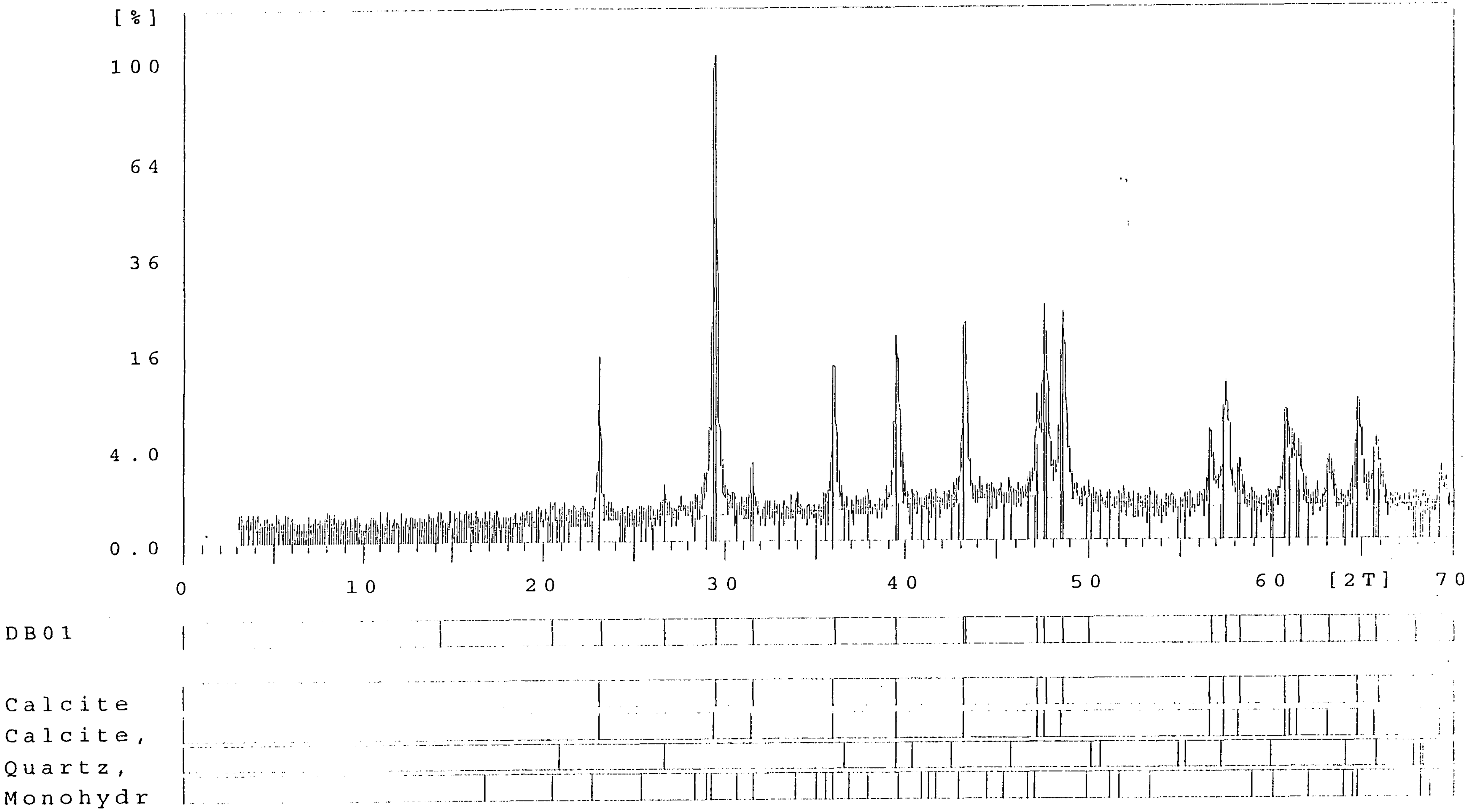
                                   3.1
```

[illegible] 5(1)

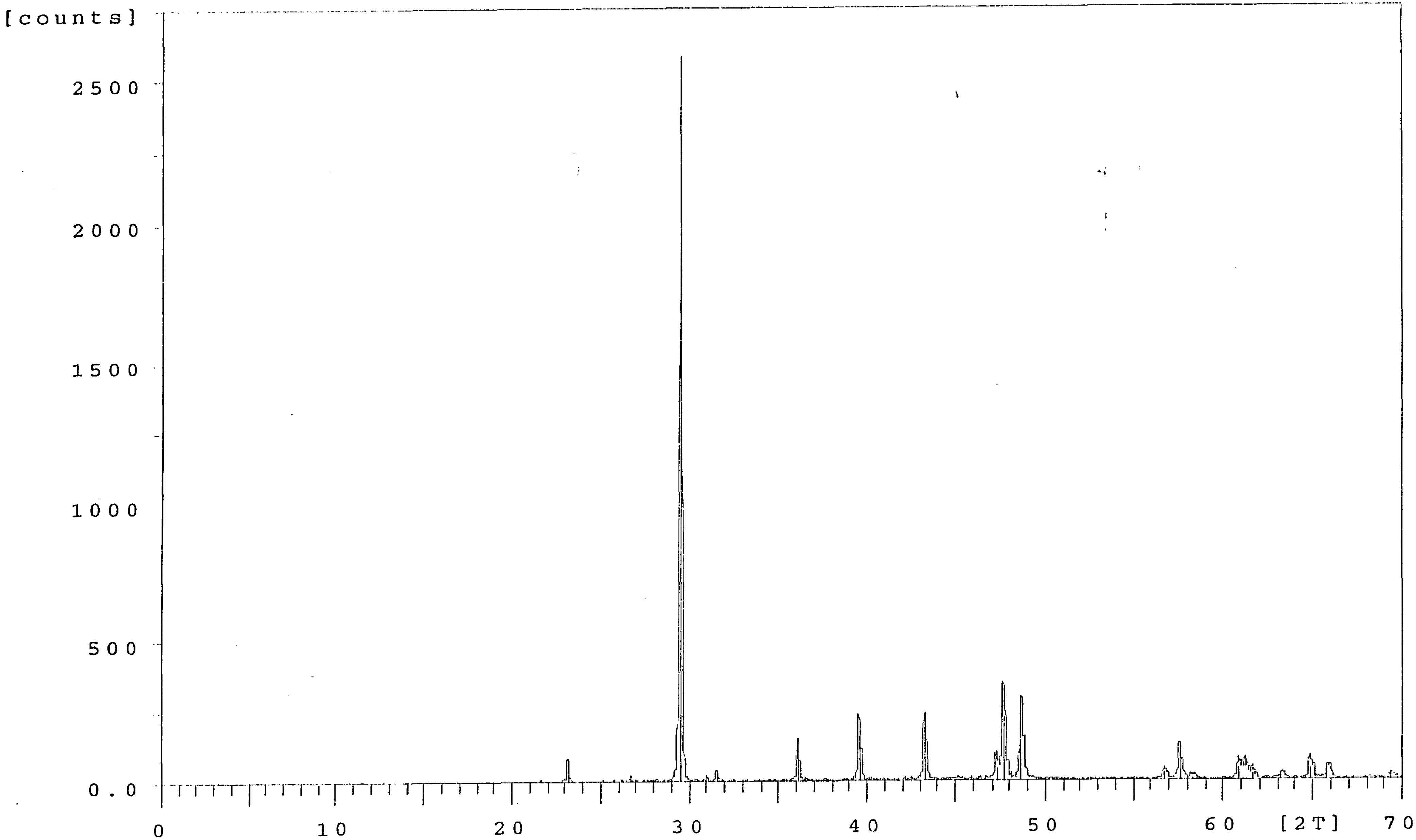
Sv 3R

1x

Sample ident.: Sv3R 14-feb-1997 14:31



Sample identification Sv10R 14-feb-1997 14:31



DB02.SD DB02.DI

1997 [illegible] Vedlegg 2 1(9)

Sv10R

xi

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File: C:\ANN\DATA\DB02.DI      1997.0043 vedlegg 2      2(4)      14-feb-1997 14
==============================================================================
NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********

P E A K    S E A R C H:

                  Input file: DB02.SD

           Start angle [°2θ]: 3.010
             End angle [°2θ]: 69.990
       Maximum d-value   [Å]: 29.32891
       Minimum d-value   [Å]: 1.34314
Maximum number of counts: 508

     Sample identification: Sv10R

              Anode material: Cu
       α1 Wavelength     [Å]: 1.54060
       α2 Wavelength     [Å]: 1.54439

Intensity measured with FIXED slit

P E A K   S E A R C H:

  d-value       Angle Tip width    Height   Background    Rel. int.  Significanc
    [Å]         [°2θ]     [°2θ]  [counts]    [counts]        [%]
 --------     -------  ---------  -------  ----------   ---------  -----------
  9.92238       8.905     0.120        11           1         0.4         0.77
  3.83656      23.165     0.120        79           2         3.1         3.09
  3.34039      26.665     0.120        15           3         0.6         1.96
  3.02551      29.500     0.160      2581           3       100.0        35.18
  2.88699      30.950     0.080        15           3         0.6         0.76
  2.83519      31.530     0.060        31           3         1.2         0.86
  2.48773      36.075     0.100       104           4         4.0         2.83
  2.27845      39.520     0.120       164           5         6.3         4.08
  2.08928      43.270     0.080       164           7         6.3         1.85
  1.92177      47.260     0.080        42           8         1.6         0.80
  1.90751      47.635     0.100       219           7         8.5         2.85
  1.87006      48.650     0.160       180           7         7.0         7.52
  1.71840      53.265     0.100         3           5         0.1         0.85
  1.62178      56.715     0.100        26           5         1.0         0.76
  1.59984      57.565     0.080        67           5         2.6         1.22
  1.58364      58.210     0.160         9           5         0.3         0.75
  1.52144      60.835     0.100        42           5         1.6         1.37
  1.50305      61.660     0.240        17           5         0.7         1.57
  1.47784      62.830     0.060         3           5         0.1         0.81
  1.47018      63.195     0.160        12           5         0.4         0.78
  1.43779      64.790     0.140        40           5         1.5         2.87
  1.41843      65.785     0.200        24           5         0.9         1.89
  1.35311      69.400     0.060        11           6         0.4         0.84

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                                     1
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File: C:\ANN\DATA\DB02.IDN      1997.0043 vedlegg 2   3(4) 14-feb-1997 14
==============================================================================
NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********

S C O R E    L I S T    L O N G:

Analysed DI file                   : C:\ANN\DATA\DB02.DI
Sample identification              : Sv10R
Last update of results file        : 14-feb-1997 14:45

Database used                      : C:\IDENTDB

MEASUREMENT PARAMETERS

Diffractometer                     : X'PERT
Start angle                        : 3.010
Final angle                        : 69.990
Step size                          : 0.020
Time per step                      : 1.0
Anode material                     : Cu
Focus                              : LFF

Date and time of measurement       : 14-feb-1997 11:13

PEAK SEARCH PARAMETERS

Minimum peak width                 : 0.00
Maximum peak width                 : 1.00
Peak base width                    : 2.00
Minimum significance               : 0.75

Number of peaks detected           : 23

SEARCH-MATCH PARAMETERS

Number of strong lines of the
reference patterns used in SEARCH  : 5
Intensity threshold                : 3.02
Confidence threshold               : 10
Minimum specimen displacement      : -100
Maximum specimem displacement      : 100
Step size in specimen displacement: 25

Restrictions file     : MINERAL

Results:

+---+-+--------+-+------+------+------+------+----+-----+--------------------+
|   |I|Card Id |#|Search|Search| Match|Rel m |Conc|Displ|Formulas            |
|   | |        | | score| displ| score|score |    |     |                    |
+---+-+--------+-+------+------+------+------+----+-----+--------------------+
|  1|*|05-0586 |1|    83|   100| 15.99|  0.80|  33|  134| CaCO3              |
|  2| |24-0027 |1|    94|   100| 13.56|  0.80|  23|  110| CaCO3              |
|  3|*|29-1489 |1|    58|   100|  2.99|  0.50|   0|  119| Al2Si2O5(OH)4!2H2O |
|  4| |06-0615 |1|    54|    50|  1.43|  0.48|   4|   84| FeO                |
+---+-+--------+-+------+------+------+------+----+-----+--------------------+

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                                     1
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File: C:\ANN\DATA\DB02.IDN     1997.0043 vedlegg 2    4(9)      14-feb-1997 14
================================================================================
NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********

+-------------------------------+
|Name                           |
|                               |
+-------------------------------+
|Calcite, syn                   |
|Calcite                        |
|Halloysite-10A                 |
|W\PIustite, syn                |
+-------------------------------+

================================================================================
```

```
File: C:\ANN\DATA\DB02.IDN     1997.0043 vedlegg 2    5(9)      14-feb-1997 14
================================================================================
NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********

+---+-+--------+-+------+------+------+-----+----+-----+------------------+
|   |I|Card Id |#|Search|Search| Match|Rel m|Conc|Displ|Formulas          |
|   | |        | | score| displ| score|score|    |     |                  |
+---+-+--------+-+------+------+------+-----+----+-----+------------------+
|  5| |06-0680 |1|    38|  -100|  2.04| 0.41|   1| -105| Cu2-xSe          |
|  6| |04-0832 |1|    46|     0|  8.33| 0.38|   0|   23| FeS              |
|  7| |04-0763 |1|    48|   100|  2.62| 0.37|   1|  127| NiCr2O4          |
|  8| |04-0835 |1|    54|   -25|  1.12| 0.37|   0|  -44| NiO              |
|  9| |30-0093 |1|    50|     0| 10.47| 0.36|   0|   12| Pd8Sb3           |
| 10| |05-0739 |1|    63|   100|  2.52| 0.36|   0|  119| MgSiO3!H2O       |
| 11| |11-0151 |1|    46|     0|  5.70| 0.34|   0|   23| FeS              |
| 12| |02-1008 |1|    46|   -25|  4.54| 0.32|   0|  -20| (Mg,Fe)3Al2Si3O12|
| 13| |12-0688 |1|    42|    50|  9.35| 0.32|   3|   51| ZnS              |
| 14| |39-1363 |1|    42|    50|  9.35| 0.32|   3|   51| ZnS              |
| 15| |36-1451 |1|    46|  -100|  2.89| 0.32|   0|  -99| ZnO              |
| 16| |29-0823 |1|    62|    50| 10.76| 0.32|   0|   73| Na2KLi(Mn,Fe)2Ti2S|
| 17| |24-0080 |1|    46|   100|  5.74| 0.30|   2|  116| FeS              |
| 18| |43-0664 |1|    39|   -25|  2.08| 0.30|   1|  -15| Ni3Si4O10(OH)2!5H2|
| 19| |05-0664 |1|    44|  -100|  2.66| 0.30|   0|  -99| ZnO              |
| 20| |09-0353 |1|    42|    25|  2.04| 0.29|   0|   35| (Mg,Fe)(Cr,Al)2O4|
| 21| |33-0670 |1|    40|    50|  4.63| 0.29|   1|   40| Fe2P             |
| 22| |10-0469 |1|    42|     0|  9.73| 0.29|   1|   12| Cu3(Ge,Fe)S4     |
| 23| |29-0718 |1|    42|   -75|  0.86| 0.29|   2|  -56| (Pt,Fe)          |
| 24| |10-0496 |1|    55|   100|  6.53| 0.28|   0|  119| KAlV2Si3O10(OH)2 |
| 25| |15-0506 |1|    43|    50|  2.78| 0.28|   0|   27| (UO2)2AlOH(VO4)2!8|
| 26| |19-0607 |1|    42|   100| 10.36| 0.27|   0|  116| (Fe,Mg)SiO3      |
| 27| |31-0635 |1|    42|   100| 10.36| 0.27|   0|  116| (Fe,Mg)SiO3      |
| 28| |25-0432 |1|    39|   100| 12.20| 0.27|   1|  116| Pb10AgBi5S18     |
| 29| |11-0695 |1|    54|     0|  7.86| 0.27|   4|   27| SiO2             |
| 30| |17-0148 |1|    52|   100|  6.21| 0.27|   0|  119| Mg(UO2)2(AsO4)2!10|
| 31| |40-0492 |1|    40|     0| 25.42| 0.27|   1|   12| AsTi3V4O13(OH)   |
| 32|*|42-0604 |1|    42|     0| 14.41| 0.27|   0|   19| K(AlFeLi)(Si3Al)O1|
| 33| |02-1231 |1|    42|   -75|  1.06| 0.27|   1|  -74| CuZn             |
| 34| |42-0565 |1|    42|    50|  4.21| 0.26|   5|   84| Cu2FeGeS4        |
| 35| |33-1144 |1|    67|   -50|  3.65| 0.26|   1|  -27| RuAs2            |
| 36| |17-0546 |1|    49|    75|  8.50| 0.26|   1|   94| KCa4F(Si2O5)4!8H2O|
| 37| |39-0359 |1|    58|    25|  3.34| 0.26|   1|   35| Mg3(SO4)2(OH)2   |
| 38| |43-0692 |1|    50|    75| 11.05| 0.26|   0|   74| KLi(Al,Li)2(Si3Al)|
| 39| |31-0462 |1|    42|   100|  5.36| 0.26|   5|  134| Cu4FeZnSn2S8     |
| 40| |13-0550 |1|    40|    25|  4.85| 0.26|   1|   13| Fe2Tl14O24       |
| 41| |39-1425 |1|    58|     0|  7.00| 0.25|   4|   34| SiO2             |
| 42| |11-0515 |1|    54|   100|  1.48| 0.25|   2|  105| Cu17.6Fe17.6S32  |
| 43| |18-1085 |1|    44|   -75|  3.66| 0.24|   0|  -52| NaMgAlF6!H2O     |
| 44| |22-1114 |1|    39|   -75|  4.81| 0.24|   0|  -87| (Nb,W,Fe,Mn)O2   |
| 45| |16-0344 |1|    46|     0|  5.77| 0.24|   1|   34| KMg3(Si3Al)O10F2 |
| 46| |37-0477 |1|    42|   100|  8.92| 0.23|   1|  123| FeS              |
| 47| |35-0640 |1|    50|   -50| 13.84| 0.23|   1|  -38| Y2(SiO4)(CO3)    |
| 48| |12-0291 |1|    39|    75|  5.83| 0.23|   0|   94| FeSe2            |
| 49| |25-0298 |1|    46|  -100|  7.20| 0.23|   1|  -84| Cu6Hg3As4S12     |
| 50| |27-0166 |1|    46|  -100|  1.37| 0.23|   3|  -84| CuFe2S3          |
| 51| |25-0843 |1|    39|  -100|  5.93| 0.23|   0| -112| Mg3Fe2(SiO4)3    |
+---+-+--------+-+------+------+------+-----+----+-----+------------------+

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xiii

Sv10R

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1997.0043 vedlegg 2 6(9)

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File: C:\ÅNN\DATA\DB02.IDN                                  14-feb-1997 14
=============================================================================
NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********

+-----------------------------+
|Name                         |
|                             |
+-----------------------------+
|Berzelianite                 |
|Troilite, syn                |
|Nichromite, syn [NR}         |
|Bunsenite, syn               |
|Mertieite-II, syn            |
|Cerolite                     |
|Troilite                     |
|Pyrope                       |
|Wurtzite-10\ITH\RG           |
|Wurtzite-8\ITH\RG            |
|Zincite, syn                 |
|Manganneptunite              |
|Troilite-2\ITH\RG, syn       |
|Pimelite                     |
|Zincite, syn                 |
|Magnesiochromite, ferroan    |
|Barringerite, syn            |
|Germanite                    |
|Platinum, ferroan            |
|Roscoelite-1\ITM\RG          |
|Vanuralite                   |
|Orthoferrosilite, magnesian  |
|Ferrosilite, magnesian       |
|Heyrovskyite, syn            |
|Cristobalite, syn            |
|Novacekite-20A, syn          |
|Tomichite                    |
|Zinnwaldite-1\ITM\RG         |
|Zhanghengite, syn            |
|Briartite, syn               |
|Anduoite                     |
|Fluorapophyllite             |
|Caminite                     |
|Lepidolite-2\ITM\RG#2        |
|Stannite, syn                |
|Avicennite                   |
|Cristobalite, syn            |
|Talnakhite, syn              |
|Ralstonite                   |
|Ashanite                     |
|Phlogopite-1\ITM\RG, syn     |
|Troilite-2\ITH\RG            |
|Iimoriite-(Y)                |
|Ferroselite, syn             |
|Aktashite                    |
|Isocubanite, syn             |
|Majorite                     |
+-----------------------------+

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1997.0043 vedlegg 2 7(9)

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File: C:\ÅNN\DATA\DB02.IDN                                  14-feb-1997 14
=============================================================================
NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********

+---+-+-------+-+------+------+------+-----+----+-----+--------------------+
|   |I|Card Id|#|Search|Search| Match|Rel m|Conc|Displ|Formulas            |
|   | |       | | score| displ| score|score|    |     |                    |
+---+-+-------+-+------+------+------+-----+----+-----+--------------------+
| 52| |05-0453|1|  5000|     0|  7.07| 0.23|   1| -134| CaCO3              |
| 53| |35-0683|1|    39|  -100|  3.17| 0.23|   0|  -88| Cu6FeSn2S8         |
| 54| |08-0028|1|    42|    50|  1.58| 0.23|   1|   62| PbTe               |
| 55| |14-0657|1|    42|    50|  7.37| 0.22|   2|   51| Ba4Ti7NbSi4O28Cl   |
| 56| |16-0695|1|    50|  -100|  5.88| 0.22|   0|  -66| Ca5Al2(OH)4Si3O12  |
| 57| |42-1392|1|    49|    75|  2.39| 0.22|   0|   94| Ni(As,S)2          |
| 58| |41-0582|1|    39|    50|  7.39| 0.22|   0|   38| Na4Ca6Mn19Li2Al8(P |
| 59| |30-0444|1|    47|  -100|  4.13| 0.22|   1|  -88| (Co,Ni,Fe)9S8      |
| 60| |18-0438|1|    46|   100|  1.08| 0.22|   0|  134| Cu1.4As0.9S2       |
| 61| |05-0418|1|  5000|     0|  8.43| 0.22|   1|  -29| SrCO3              |
| 62| |22-1121|1|    45|  -100| 13.37| 0.22|   0|  -77| SrTi21O38          |
| 63| |26-1380|1|    39|   100|  5.39| 0.22|   0|  134| NaNbO3             |
| 64| |11-0508|1|    39|   -25|  8.11| 0.21|   0|  -55| Pd17Se15           |
| 65| |15-0800|1|    40|   100| 17.07| 0.21|   1|  119| Na2CO3!10H2O       |
| 66| |30-0486|1|    42|  -100|  4.21| 0.21|   2|  -84| Cu6Fe2SnS8         |
| 67| |37-0471|1|    54|   100|  4.20| 0.21|  11|  119| CuFeS2             |
| 68| |18-0889|1|    48|  -100|  1.89| 0.21|   4| -127| Ni3Se4             |
| 69| |20-0222|1|    39|  -100|  8.53| 0.21|   1| -123| (Ca,Pb)ZnSiO4      |
| 70| |20-0587|1|    41|   100|  9.56| 0.21|   1|   95| Pb2Mn2(Si2O7)O2    |
| 71| |25-0597|1|    42|   100|  5.38| 0.21|   0|   95| Pd5Sb2             |
| 72| |42-1414|1|    42|    75|  6.55| 0.20|   0|   74| K(Mg,Fe+2)3(Al,Fe+ |
| 73| |18-0877|1|    46|   -75|  3.48| 0.20|   1|  -52| (Fe,Ni)            |
| 74| |39-0368|1|    39|     0|  5.50| 0.20|   1|   27| Ca3Al2(SiO4)3      |
| 75| |35-0558|1|    39|     0|  3.87| 0.20|   0|   12| (Ni,Fe)SO4!H2O     |
| 76| |22-0990|1|    39|    25|  6.65| 0.20|   0|   35| Y2FeBe2Si2O10      |
| 77| |12-0646|1|    63|    25|  0.99| 0.20|   2|   26| Cu3(As,V)S4        |
| 78| |35-0604|1|    39|   -75|  5.14| 0.20|   1|  -52| Na2Zr2Be(PO4)4     |
| 79| |26-0832|1|    47|    25|  9.09| 0.20|   1|   48| Pb2CrO5            |
| 80| |25-0288|1|    50|    25|  2.37| 0.20|   1|   59| CuFeS2             |
| 81| |16-0155|1|    39|   -75|  4.53| 0.20|   0|  -87| Ca3ZrSi2O9         |
| 82| |08-0001|1|    56|   100|  2.84| 0.19|   1|   81| (Cu,Co,Ni)3Se4     |
| 83| |36-0395|1|    46|     0|  5.01| 0.19|   6|   16| Cu13Ge2Fe2S16      |
| 84| |29-0322|1|    39|     0|  5.37| 0.19|   0|   12| Ca2F2CO3           |
| 85| |29-0210|1|    58|   100|  3.49| 0.18|   0|  119| Ba(UO2)2(AsO4)2!10 |
| 86| |17-0644|1|    40|    50|  2.73| 0.18|   0|   80| CuRh2S4            |
| 87| |39-1369|1|    39|  -100|  6.32| 0.18|   0|  -99| Ca2MgCr2(SiO4)(Si2 |
| 88| |38-0399|1|    41|   100|  6.28| 0.18|   0|  116| Hg3(AsO4)          |
| 89| |41-0591|1|    58|   100|  2.99| 0.18|   9|  105| Cu10Fe4ZnGe2S16    |
| 90| |25-0294|1|    54|   -25|  6.28| 0.17|   0|  -52| CuPbTlAs2S5        |
| 91| |15-0378|1|    42|  -100|  5.38| 0.17|   0|  -88| Be2AsO4(OH)!4H2O   |
| 92| |15-0069|1|    39|   -75|  2.60| 0.17|   0|  -52| (Y,Ca,Na)F2        |
| 93| |18-0670|1|    42|   100|  5.40| 0.17|   2|  123| MgFeAlSiBO         |
| 94| |02-0520|1|    39|    25|  2.84| 0.17|   0|   20| (Mg,Fe)SiO3        |
| 95| |21-0974|1|    54|   -50|  6.67| 0.16|   2|  -51| NiSO4!H2O          |
| 96| |39-0326|1|    45|     0|  5.20| 0.16|   0|   12| CuPb8(AsO3)2O3Cl5  |
| 97| |07-0377|1|    46|   -50|  4.71| 0.16|   0|  -51| Fe-Te-O            |
| 98| |25-0287|1|    42|     0|  3.41| 0.16|   1|   34| Cu9(Fe,Ni)8S16     |
+---+-+-------+-+------+------+------+-----+----+-----+--------------------+

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SV10R

[redacted]

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File: C:\ÅNN\DATA\DB02.IDN    1997.0043 vedlegg 2  8(1)    14-feb-1997 14
============================================================================
NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********

+-------------------------------+
|Name                           |
|                               |
+-------------------------------+
|Aragonite, syn                 |
|Chatkalite                     |
|Altaite                        |
|Baotite                        |
|Cebollite                      |
|Gersdorffite-\ITPa3\RG         |
|Griphite                       |
|Cobaltpentlandite              |
|Sinnerite                      |
|Strontianite, syn              |
|Crichtonite                    |
|Natroniobite                   |
|Palladseite, syn               |
|Natron, syn                    |
|Mawsonite                      |
|Chalcopyrite                   |
|Tr\PIustedtite                 |
|Esperite, syn                  |
|Kentrolite, syn                |
|Stibiopalladinite              |
|Biotite-1\ITM\RG               |
|Unnamed mineral, syn [NR]      |
|Grossular                      |
|Dwornikite                     |
|Gadolinite-(Y), heated         |
|Arsenosulvanite                |
|Gainesite                      |
|Phoenicochroite, syn           |
|Chalcopyrite                   |
|Baghdadite, syn                |
|Tyrrellite                     |
|Germanite                      |
|Brenkite                       |
|Heinrichite, syn               |
|Cuprorhodsite, syn             |
|Shuiskite                      |
|Chursinite                     |
|Renierite                      |
|Wallisite                      |
|Bearsite                       |
|Gagarinite-(Y)                 |
|Kornerupine                    |
|Enstatite, ferroan             |
|Dwornikite, syn                |
|Freedite                       |
|Blakeite                       |
|Talnakhite                     |
+-------------------------------+

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```
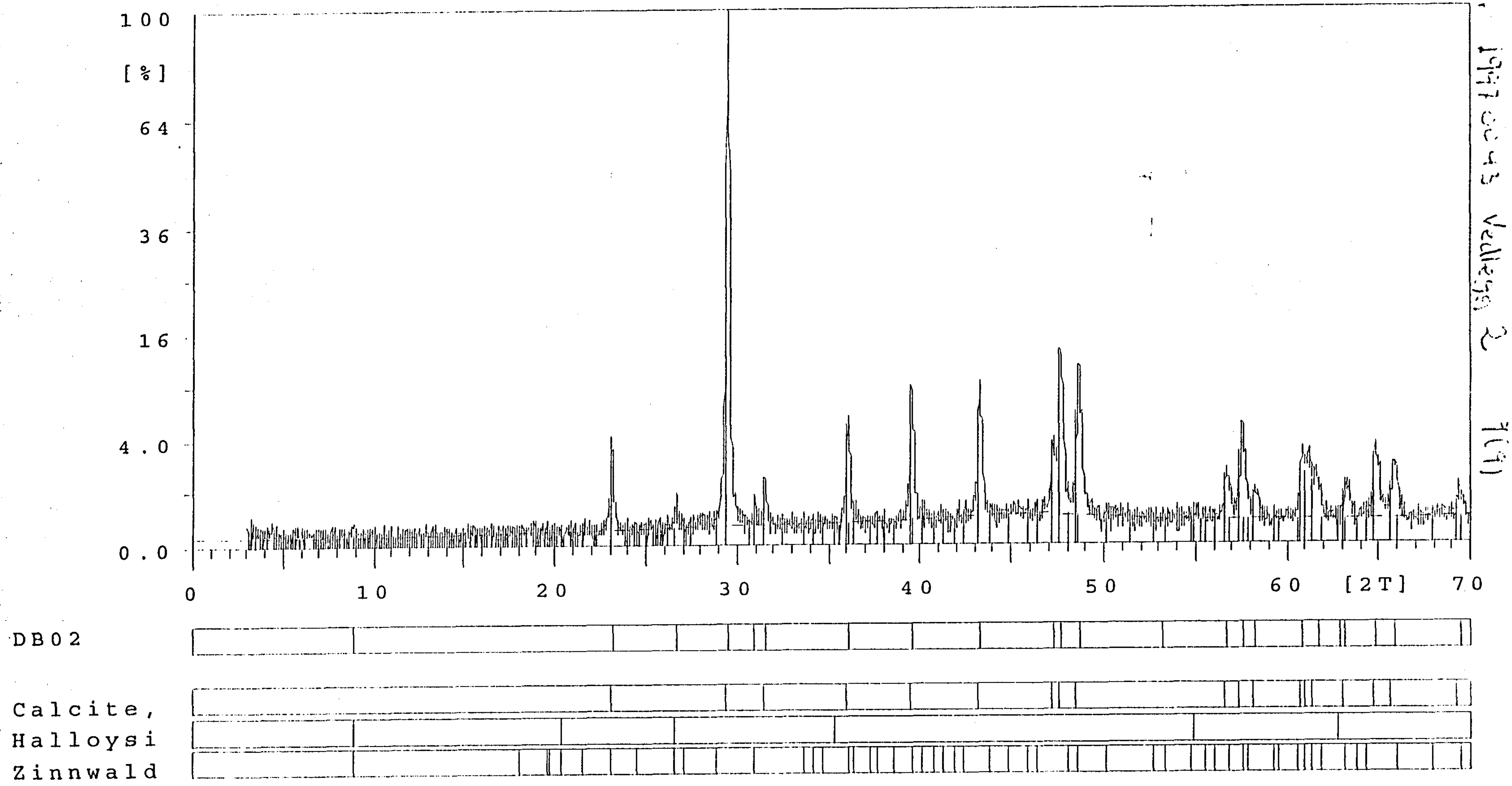

Sv 10R

xv

Sample ident.: Sv10R 14-feb-1997 14:45



1997 00 43 Vedlegg 2

7(9)

Sv10R

xvi

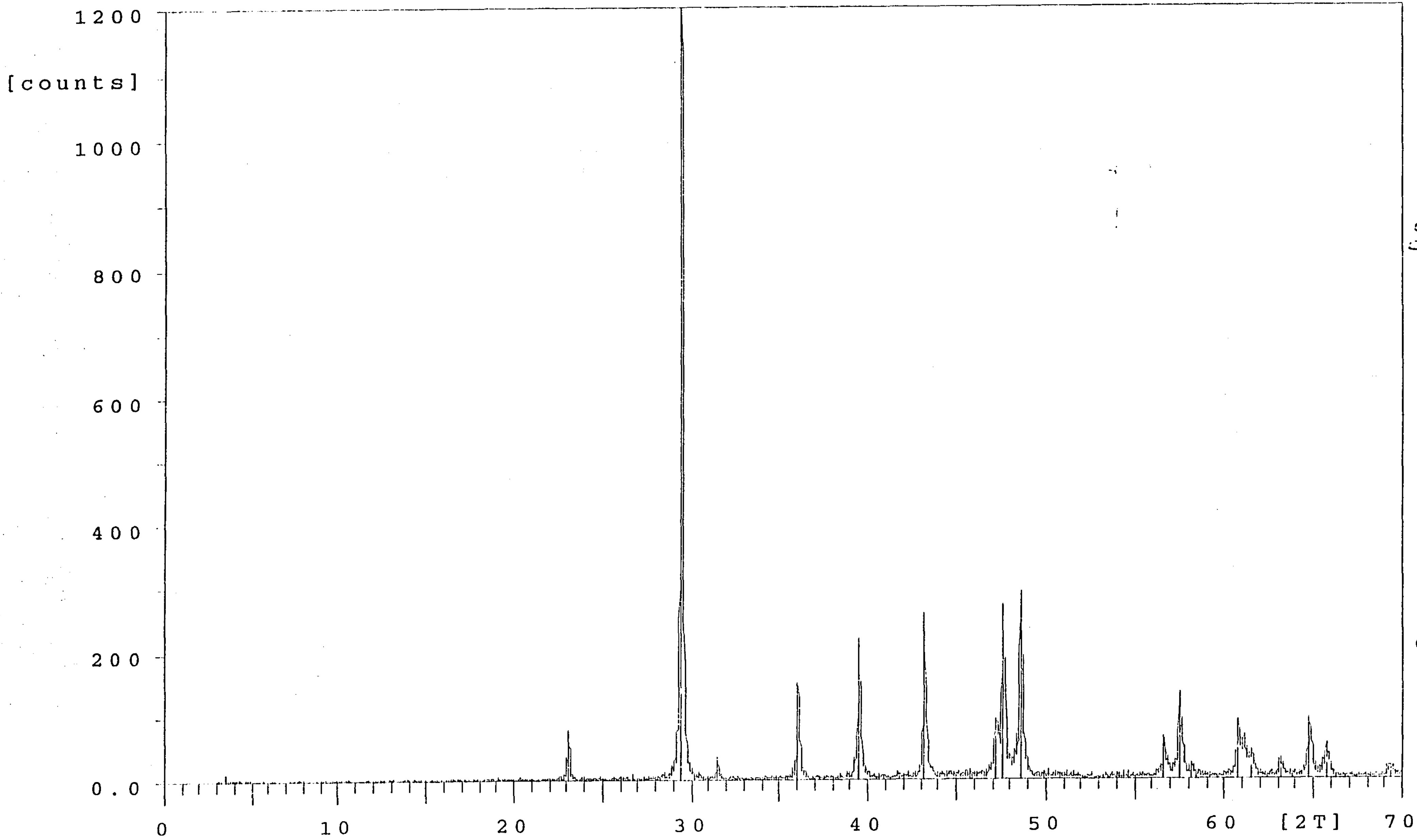
Sample identification Sv15R

14-feb-1997 14:49

1997.0043 Vedlegg 3

1(1)

Sv15R



DB03.SD

DB03.DI

[redacted]

1997.0043 vedlegg 3 2(4)

```
File: C:\ANN\DATA\DB03.DI                                              14-feb-1997 14
=====================================================================================
NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********

P E A K   S E A R C H:

              Input file: DB03.SD

         Start angle [°2θ]: 3.010
           End angle [°2θ]: 69.990
      Maximum d-value  [Å]: 29.32891
      Minimum d-value  [Å]: 1.34314
 Maximum number of counts: 347

    Sample identification: Sv15R

           Anode material: Cu
       α1 Wavelength   [Å]: 1.54060
       α2 Wavelength   [Å]: 1.54439

Intensity measured with FIXED slit

P E A K  S E A R C H:

  d-value      Angle Tip width    Height   Background   Rel. int.  Significanc
   [Å]        [°2θ]    [°2θ]    [counts]    [counts]       [%]
  --------    ------- ---------  -------   ----------   ---------  -----------
 25.15205      3.510     0.060       12            0         1.0         0.91
  3.84721     23.100     0.120       79            2         6.6         2.44
  3.03003     29.455     0.140     1204            4       100.0        14.93
  2.84002     31.475     0.060       31            3         2.6         1.11
  2.49174     36.015     0.080      125            4        10.4         1.53
  2.28150     39.465     0.080      164            5        13.6         1.37
  2.09158     43.220     0.060      180            7        14.9         0.91
  1.92369     47.210     0.120       58            8         4.8         1.03
  1.91015     47.565     0.080      164            8        13.6         1.65
  1.87241     48.585     0.100      161            8        13.4         2.91
  1.62388     56.635     0.120       26            5         2.2         0.79
  1.60251     57.460     0.080       62            5         5.2         1.43
  1.58401     58.195     0.200        7            5         0.6         0.96
  1.52336     60.750     0.120       42            5         3.5         2.12
  1.50679     61.490     0.200       18            5         1.5         0.80
  1.47143     63.135     0.160       13            5         1.1         1.14
  1.43868     64.745     0.100       44            5         3.6         1.27
  1.41987     65.710     0.160       19            5         1.6         1.06
  1.35457     69.315     0.320        6            5         0.5         1.60

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                                          1
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1997.0043 vedlegg 3 3(4)

```
File: C:\ANN\DATA\DB03.IDN                                             14-feb-1997 15
=====================================================================================
NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********

S C O R E   L I S T   L O N G:

Analysed DI file                   : C:\ANN\DATA\DB03.DI
Sample identification              : Sv15R
Last update of results file        : 14-feb-1997 15:00

Database used                      : C:\IDENTDB

MEASUREMENT PARAMETERS

Diffractometer                     : X'PERT
Start angle                        : 3.010
Final angle                        : 69.990
Step size                          : 0.020
Time per step                      : 1.0
Anode material                     : Cu
Focus                              : LFF

Date and time of measurement       : 14-feb-1997 12:09

PEAK SEARCH PARAMETERS

Minimum peak width                 : 0.00
Maximum peak width                 : 1.00
Peak base width                    : 2.00
Minimum significance               : 0.75

Number of peaks detected           : 19

SEARCH-MATCH PARAMETERS

Number of strong lines of the
reference patterns used in SEARCH  : 5
Intensity threshold                : 3.02
Confidence threshold               : 10
Minimum specimen displacement      : -100
Maximum specimem displacement      : 100
Step size in specimen displacement: 25

Restrictions file     : MINERAL

Results:

+---+-+--------+-+-------+-------+-------+-----+----+-----+--------------------+
|   |I|Card Id |#|Search |Search | Match |Rel m|Conc|Displ|Formulas            |
|   | |        | | score | displ | score |score|    |     |                    |
+---+-+--------+-+-------+-------+-------+-----+----+-----+--------------------+
|  1|*|05-0586 |1|     97|   100 |  17.47| 0.87|  58|  119| CaCO3              |
|  2| |24-0027 |1|     97|    25 |  13.86| 0.82|  48|   35| CaCO3              |
|  3| |06-0615 |1|     63|   -25 |   1.46| 0.49|   8|  -20| FeO                |
|  4| |18-0438 |1|     54|   100 |   2.13| 0.43|   0|  110| Cu1.4As0.9S2       |
+---+-+--------+-+-------+-------+-------+-----+----+-----+--------------------+

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                                          1
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1997.043 vedlegg 3 4 (7)

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File: C:\ANN\DATA\DB03.IDN
                                                          14-feb-1997 15
==========================================================================
NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********
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```
+------------------------------+
|Name                          |
|                              |
+------------------------------+
|Calcite, syn                  |
|Calcite                       |
|W\PIustite, syn               |
|Sinnerite                     |
+------------------------------+

==========================================================================
```

1997.043 vedlegg 3 5 (7)

```
File: C:\ANN\DATA\DB03.IDN
                                                          14-feb-1997 15
==========================================================================
NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********
```

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+---+-+-------+-+------+------+-------+-----+----+-----+--------------------+
|   |I|Card Id|#|Search|Search|  Match|Rel m|Conc|Displ|Formulas            |
|   | |       | | score| displ|  score|score|    |     |                    |
+---+-+-------+-+------+------+-------+-----+----+-----+--------------------+
|  5| |07-0007|1|    42|   100|   2.51| 0.36|   1|  110| NH4Cl              |
|  6| |08-0012|1|    38|  -100|   1.76| 0.35|   0|  -84| AgSb2(O,OH,H2O)6   |
|  7| |35-0582|1|    42|   100|   4.81| 0.34|  11|   95| Cu2FeSnS4          |
|  8| |41-0602|1|    50|   100|   1.03| 0.34|   1|  134| (Ir,Os,Ru)         |
|  9| |20-0133|1|    44|   100|   6.09| 0.34|   0|  105| (Na,K)2(Ba,Ca,Sr)2 |
| 10| |04-0836|1|    33|   -75|   0.65| 0.33|  16|  -74| Cu                 |
| 11| |42-0423|1|    38|     0|  13.26| 0.32|   3|   34| CaTiO3             |
| 12| |04-0728|1|    43|   -50|   5.67| 0.31|   1|  -31| Ca3Mg(SiO4)2       |
| 13| |16-0696|1|    38|   100|   5.96| 0.31|   1|  105| (Re,Ca,Fe)0.90NbTi |
| 14| |38-0430|1|    46|  -100|   3.12| 0.31|   1|  -66| MnFe2O4            |
| 15| |05-0739|1|    42|   100|   2.18| 0.31|   1|  119| MgSiO3!H2O         |
| 16| |06-0598|1|    42|   -50|   0.93| 0.31|   3|  -27| Ir                 |
| 17| |04-0835|1|    42|     0|   0.89| 0.30|   4|   23| NiO                |
| 18| |14-0603|1|    39|    25|   6.71| 0.29|   0|   35| NaNbO3             |
| 19| |33-0126|1|    39|   -50|   7.29| 0.29|   0|  -38| NiAs2              |
| 20| |18-1484|1|    41|   100|   4.07| 0.29|   0|  105| ZnMn2O4            |
| 21| |25-1426|1|    38|   -75|   4.06| 0.29|   1|  -41| (Cu,Fe)8(Pb,Cd)S8  |
| 22| |11-0014|1|    38|     0|   6.89| 0.29|   1|   16| NiAs2              |
| 23| |24-0518|1|    40|     0|   6.59| 0.29|   0|   16| NiAs2              |
| 24| |21-1276|1|    39|  -100|   3.43| 0.29|   4|  -66| TiO2               |
| 25| |18-0658|1|    38|  -100|   2.53| 0.28|   1|  -66| Fe2TiO4            |
| 26| |04-0763|1|    43|    25|   1.95| 0.28|   1|   35| NiCr2O4            |
| 27| |05-0737|1|    36|   -25|   5.26| 0.28|   0|  -20| (Sr,Ca)Al3(PO4)(SO |
| 28| |17-0546|1|    43|     0|   9.05| 0.27|   3|   16| KCa4F(Si2O5)4!8H2O |
| 29| |19-0392|1|    38|     0|   4.66| 0.27|   0|   27| Cu2(WO4)(OH)2      |
| 30| |30-0093|1|    54|     0|   7.86| 0.27|   1|   34| Pd8Sb3             |
| 31| |31-0462|1|    46|    50|   5.60| 0.27|  11|   66| Cu4FeZnSn2S8       |
| 32| |41-1431|1|    38|    50|   6.36| 0.26|   1|   84| CaWO4              |
| 33| |11-0695|1|    54|   -75|   7.68| 0.26|   8|  -85| SiO2               |
| 34| |19-0750|1|    38|    50|  13.65| 0.26|   0|   84| (Mg4Al4)(Al4Si2)O2 |
| 35| |29-0133|1|    42|   -25|   5.75| 0.26|   0|  -48| (Pt,Pd)4Sb3        |
| 36| |38-0478|1|    38|    75|   4.68| 0.26|   0|   65| Mg6Al2(OH)18!4H2O  |
| 37| |39-0326|1|    43|  -100|   8.30| 0.26|   0| -123| CuPb8(AsO3)2O3Cl5  |
| 38| |08-0001|1|    41|   100|   3.89| 0.26|   1|  130| (Cu,Co,Ni)3Se4     |
| 39| |39-0329|1|    42|  -100|   3.11| 0.26|   0|  -99| CuIr2S4            |
| 40| |25-0264|1|    42|  -100|   4.63| 0.26|   0|  -84| Cu6As4S9           |
| 41| |18-0672|1|    37|  -100|   4.89| 0.26|   0| -123| NaMnZn2(Ti,Fe)6Ti1 |
| 42|*|31-1082|1|    39|   100|   7.20| 0.26|   0|  116| KNaCaMg5Si8O22(OH) |
| 43| |09-0287|1|    43|   100|   3.06| 0.26|   1|  112| ((Pt,Pd,Ni)S)      |
| 44| |18-1362|1|    38|    25|   3.06| 0.25|   1|   59| Th(Ca,Ce)(CO3)2F2! |
| 45| |39-1425|1|    58|     0|   7.04| 0.25|  11|   16| SiO2               |
| 46| |29-0322|1|    38|   -75|   7.28| 0.25|   0|  -59| Ca2F2CO3           |
| 47| |25-1379|1|    37|    50|   7.23| 0.25|   1|   77| MgAlBO4            |
| 48| |09-0423|1|    33|   -25|   1.99| 0.25|   0|    9| CuFeS2             |
| 49| |25-0598|1|    38|   -50|   6.67| 0.25|   0|  -27| Pd11(Sb,As)4       |
| 50| |29-0914|1|    39|    75|   3.71| 0.25|   1|   85| MoSe2              |
| 51| |35-1351|1|    38|   100|   4.93| 0.25|   5|  105| Cu2FeSnS4          |
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xix

1997.043 Vedlegg 3 6(9)

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File: C:\ANN\DATA\DB03.IDN                                  14-feb-1997 15
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NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********

+------------------------------+
|Name                          |
|                              |
+------------------------------+
|Salammoniac, syn              |
|Stetefeldtite                 |
|Stannite                      |
|Iridium, osmian               |
|Barytolamprophyllite          |
|Copper, syn                   |
|Perovskite, syn               |
|Merwinite, syn                |
|Aeschynite                    |
|Iwakiite                      |
|Cerolite                      |
|Iridium, syn                  |
|Bunsenite, syn                |
|Lueshite, syn                 |
|Rammelsbergite                |
|Hetaerolite                   |
|Shadlunite                    |
|Rammelsbergite, syn           |
|Rammelsbergite                |
|Rutile, syn                   |
|Ulvospinel, syn               |
|Nichromite, syn [NR]          |
|Svanbergite, calcian          |
|Fluorapophyllite              |
|Cuprotungstite, syn           |
|Mertieite-II, syn             |
|Stannite, syn                 |
|Scheelite, syn                |
|Cristobalite, syn             |
|Sapphirine-2\ITM\RG           |
|Genkinite                     |
|Meixnerite                    |
|Freedite                      |
|Tyrrellite                    |
|Cuproiridsite                 |
|Sinnerite, syn                |
|Landauite                     |
|Richterite, potassian         |
|Cooperite                     |
|Thorbastn\PIasite             |
|Cristobalite, syn             |
|Brenkite                      |
|Sinhalite, syn                |
|Chalcopyrite                  |
|Mertieite-I                   |
|Drysdallite-2\ITH\RG          |
|Stannite, syn                 |
+------------------------------+

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1997.043 Vedlegg 3 7(9)

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File: C:\ANN\DATA\DB03.IDN                                  14-feb-1997 15
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NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********

+---+-+--------+-+------+------+------+-----+----+-----+------------------+
|   |I|Card Id |#|Search|Search| Match|Rel m|Conc|Displ|Formulas          |
|   | |        | | score| displ| score|score|    |     |                  |
+---+-+--------+-+------+------+------+-----+----+-----+------------------+
| 52| |26-0292 |1|    37|  -100|  4.43| 0.25|   2|  -81| Ca3Al2(SiO4)3    |
| 53| |22-1092 |1|    37|    25| 14.08| 0.24|   0|   59| CuTeO3           |
| 54| |22-0349 |1|    37|   -75|  2.18| 0.24|   4|  -74| (Fe,Mg)(Cr,Fe)2O4|
| 55| |35-0706 |1|    40|     0|  4.36| 0.24|   0|   16| (Na,Cs)Bi(Ta,Nb,Sb|
| 56| |03-0801 |1|    34|   -50|  3.86| 0.24|   0|  -40| Ca3Al2(SiO4,CO3,OH|
| 57| |22-0729 |1|    40|   -25|  1.93| 0.24|   1|    9| Hg(S,Se)         |
| 58| |21-0974 |1|    38|  -100|  9.73| 0.24|   1| -116| NiSO4!H2O        |
| 59| |05-0623 |1|    35|   100|  5.93| 0.24|   0|   88| Fe-La-U-Ca-Ti-O-OH|
| 60| |29-1344 |1|    38|     0|  4.94| 0.24|  11|   16| Tl2S             |
| 61| |34-1316 |1|    37|    25|  4.70| 0.23|   0|   59| (Ca,Ce)(Nb,Ta,Ti)2|
| 62| |11-0515 |1|    46|     0|  1.40| 0.23|   5|   34| Cu17.6Fe17.6S32  |
| 63| |40-0492 |1|    40|  -100| 22.14| 0.23|   2|  -99| AsTi3V4O13(OH)   |
| 64| |08-0003 |1|    43|  -100|  4.13| 0.23|   0|  -84| Pb5Au(Te,Sb)4Sx  |
| 65| |25-0774 |1|    34|    50|  7.06| 0.23|   1|   40| Mn6CaFeAl(PO4)6F2|
| 66| |08-0028 |1|    42|   -25|  1.56| 0.22|   2|  -24| PbTe             |
| 67| |29-0823 |1|    55|  -100|  7.53| 0.22|   1|  -66| Na2KLi(Mn,Fe)2Ti2S|
| 68| |42-1345 |1|    53|   -25|  5.25| 0.22|   1|  -24| CoAsS            |
| 69| |05-0453 |1|  5000|     0|  6.71| 0.22|   1|  296| CaCO3            |
| 70| |35-0525 |1|    43|   100|  3.12| 0.21|   0|  134| (Cu,Zn,Ag)12(As,Sb|
| 71| |41-1498 |1|    46|     0|  5.18| 0.21|   1|   34| (Cu10Hg2)Sb4S12  |
| 72| |05-0418 |1|  5000|     0|  8.03| 0.21|   1| -100| SrCO3            |
| 73| |20-0669 |1|    39|     0| 13.38| 0.21|   6|   16| MgCO3!3H2O       |
| 74| |18-0972 |1|    83|   -50|  1.83| 0.20|  11|  -51| PtS              |
| 75| |11-0306 |1|    39|    50|  5.81| 0.20|   2|   49| CaCuAsO4(OH)     |
| 76| |25-0298 |1|    38|  -100|  6.20| 0.20|   2| -105| Cu6Hg3As4S12     |
| 77| |02-1282 |1|    34|   -50|  3.97| 0.20|   1|  -55| Li3Na3Al2F12     |
| 78| |15-0682 |1|    39|     0|  3.96| 0.20|   0|   16| PbSeO4           |
| 79| |39-0368 |1|    40|   -50|  5.12| 0.19|   3|  -40| Ca3Al2(SiO4)3    |
| 80| |16-0155 |1|    35|  -100|  4.31| 0.19|   2|  -88| Ca3ZrSi2O9       |
| 81| |43-1468 |1|    42|    75|  2.25| 0.19|   1|   80| CuCr2S4          |
| 82| |33-0332 |1|    34|   100|  8.72| 0.19|   1|  105| CeNbO4           |
| 83| |42-0590 |1|    38|   -25| 20.94| 0.19|   0|  -48| CaV2O6!4H2O      |
| 84| |35-0672 |1|    42|   100|  3.47| 0.18|   1|  119| (Cs,Na)SbTa4O12  |
| 85| |33-0895 |1|    34|   100|  9.12| 0.18|   4|   95| MnH(AsO4)!H2O    |
| 86| |41-0582 |1|    40|    50|  6.12| 0.18|   1|   38| Na4Ca6Mn19Li2Al8(P|
| 87| |20-0240 |1|    39|     0|  9.72| 0.18|   0|   12| Ca5(SiO4)2(OH)2  |
| 88| |32-0680 |1|    40|    25|  6.11| 0.18|   0|   15| NdNbO4           |
| 89| |16-0609 |1|    58|   -75|  4.47| 0.18|   1|  -65| NaAl8V10O38!30H2O|
| 90| |22-0990 |1|    38|     0|  5.89| 0.18|   0|   27| Y2FeBe2Si2O10    |
| 91| |39-0195 |1|    39|   -50| 11.37| 0.18|   3|  -16| Ca3Zr(Si2O9)O2   |
| 92| |29-1338 |1|    37|    25|  5.97| 0.18|   0|   26| CuTlHgAsS4       |
| 93| |22-0539 |1|    38|   -75|  5.37| 0.17|   1|  -41| Ca3Si2O7         |
| 94| |35-0640 |1|    37|   -50| 10.08| 0.17|   1|  -16| Y2(SiO4)(CO3)    |
| 95| |12-0688 |1|    46|  -100|  4.93| 0.17|   9|  -84| ZnS              |
| 96| |39-1363 |1|    46|  -100|  4.93| 0.17|   9|  -84| ZnS              |
| 97| |14-0189 |1|    39|     0|  3.15| 0.17|   2|   16| (Sn,Pb,Zn)S      |
| 98| |18-0791 |1|    39|    75|  3.61| 0.16|   0|   94| (Mn,Mg)(Mn,Fe)2O4|
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Sv 15R

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NGU-lab XRD-analyser Philips X'Pert MPD Operator: Andreas Grimstvedt ********

+-------------------------------+
|Name                           |
|                               |
+-------------------------------+
|Grossular                      |
|Balyakinite                    |
|Donathite                      |
|Natrobistantite                |
|Grossular, hydroxylian         |
|Metacinnabar, selenian         |
|Dwornikite, syn                |
|Davidite                       |
|Carlinite, syn                 |
|Vigezzite                      |
|Talnakhite, syn                |
|Tomichite                      |
|Nagyagite, syn                 |
|Griphite                       |
|Altaite                        |
|Manganneptunite                |
|Cobaltite                      |
|Aragonite, syn                 |
|Giraudite                      |
|Tetrahedrite, mercurian, syn   |
|Strontianite, syn              |
|Nesquehonite, syn              |
|Cooperite, syn                 |
|Conichalcite                   |
|Aktashite                      |
|Cryolithionite                 |
|Kerstenite, syn [NR]           |
|Grossular                      |
|Baghdadite, syn                |
|Florensovite                   |
|Fergusonite-β-(Ce), syn        |
|Rossite                        |
|Cesstibtantite                 |
|Krautite, syn                  |
|Griphite                       |
|Calcio-chondrodite, syn        |
|Fergusonite-β-(Nd)             |
|Vanalite                       |
|Gadolinite-(Y), heated         |
|Baghdadite, syn                |
|Routhierite                    |
|Rankinite                      |
|Iimoriite-(Y)                  |
|Wurtzite-10\ITH\RG             |
|Wurtzite-8\ITH\RG              |
|Teallite, zincian              |
|Hausmannite                    |
+-------------------------------+

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                                3.1
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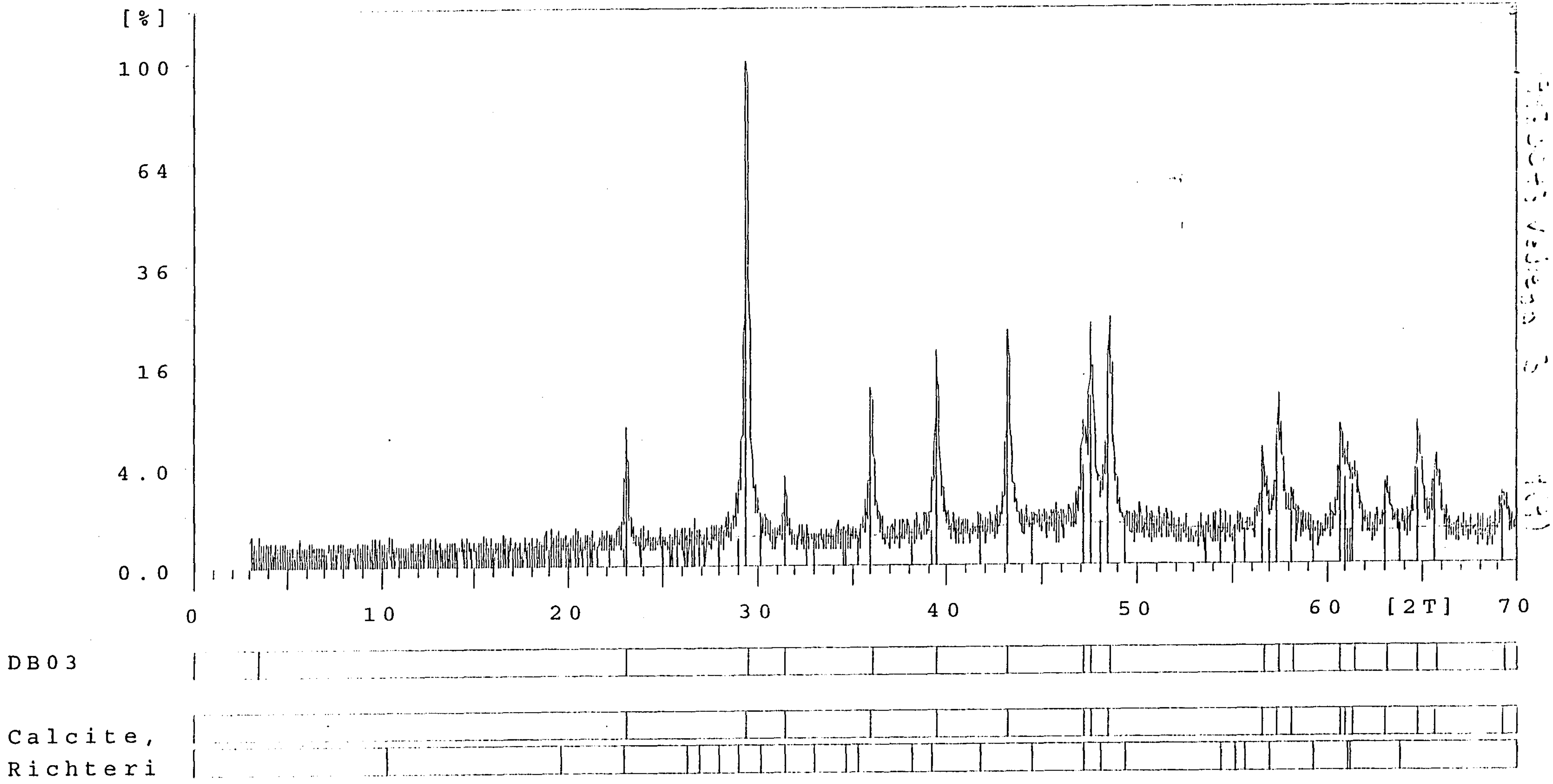
SV15R

xxi

Sample ident.: Sv15R 14-feb-1997 15:00

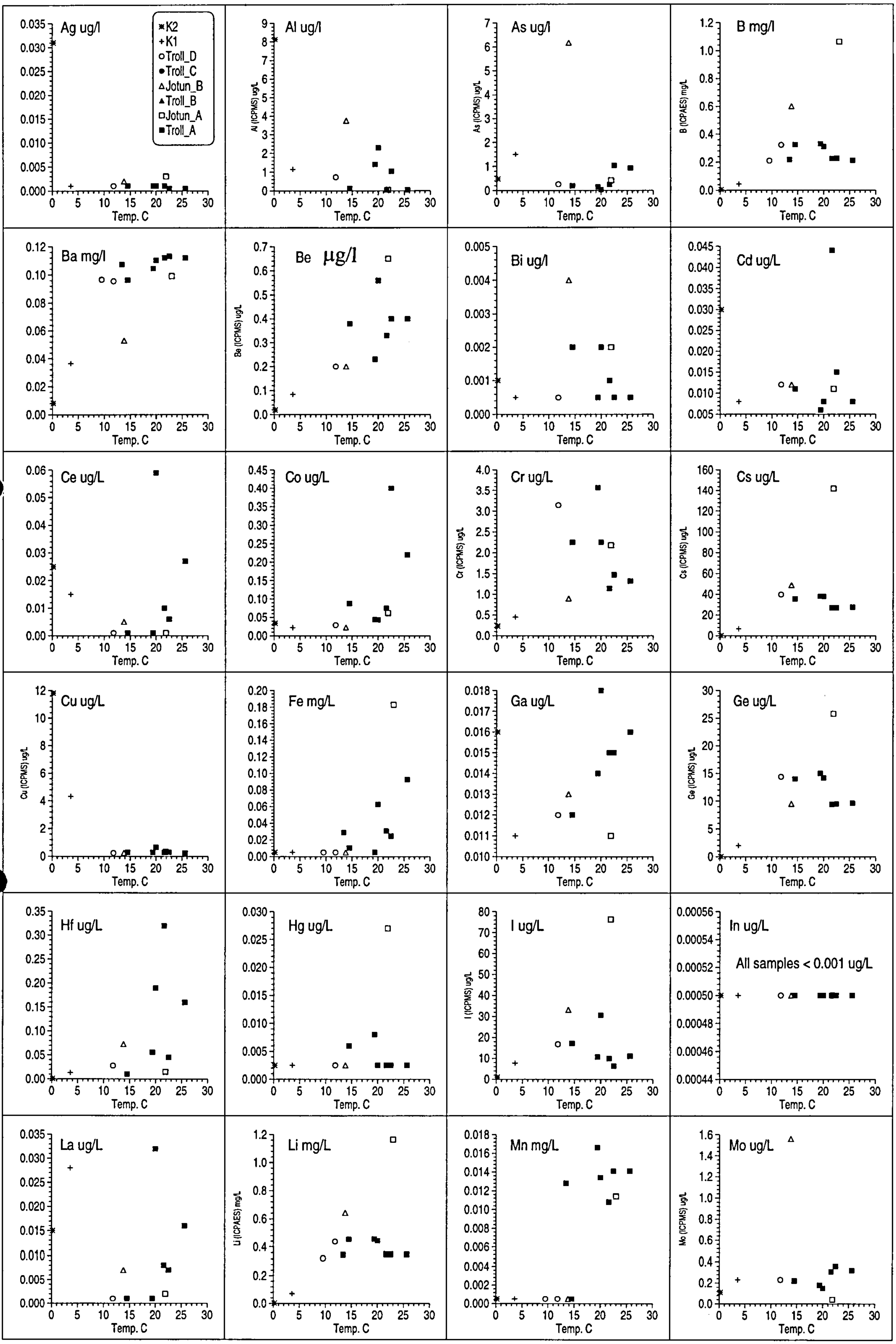


Sv15R

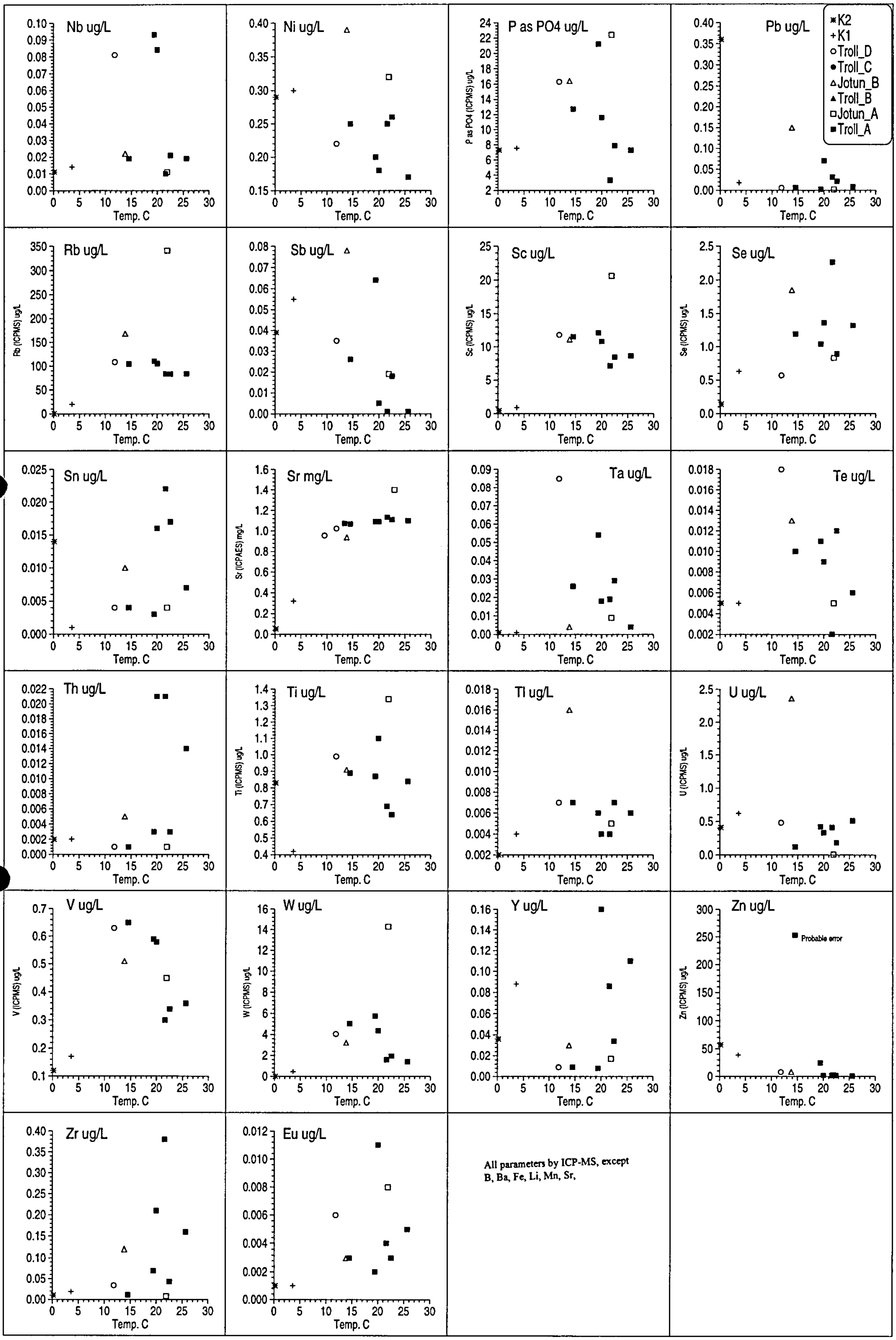
Appendix 7

Boxplots / x-y plots illustrating distribution of analytical parameters versus temperature and as a function of spring type

Samples below analytical detection limit are plotted at half the detection limit.



In cases where the parameter is below the analytical detection limit, a value of half the detection limit is plotted.



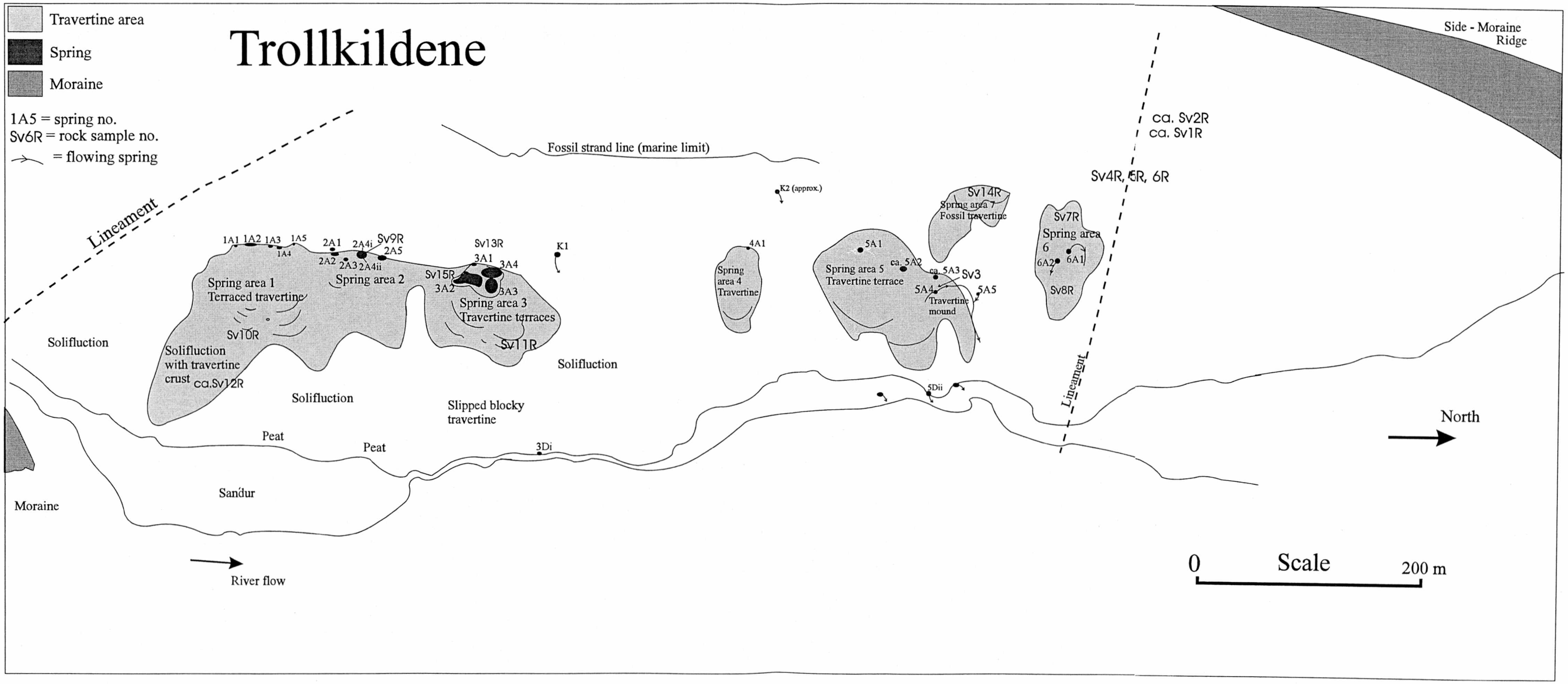
All parameters by ICP-MS, except B, Ba, Fe, Li, Mn, Sr,

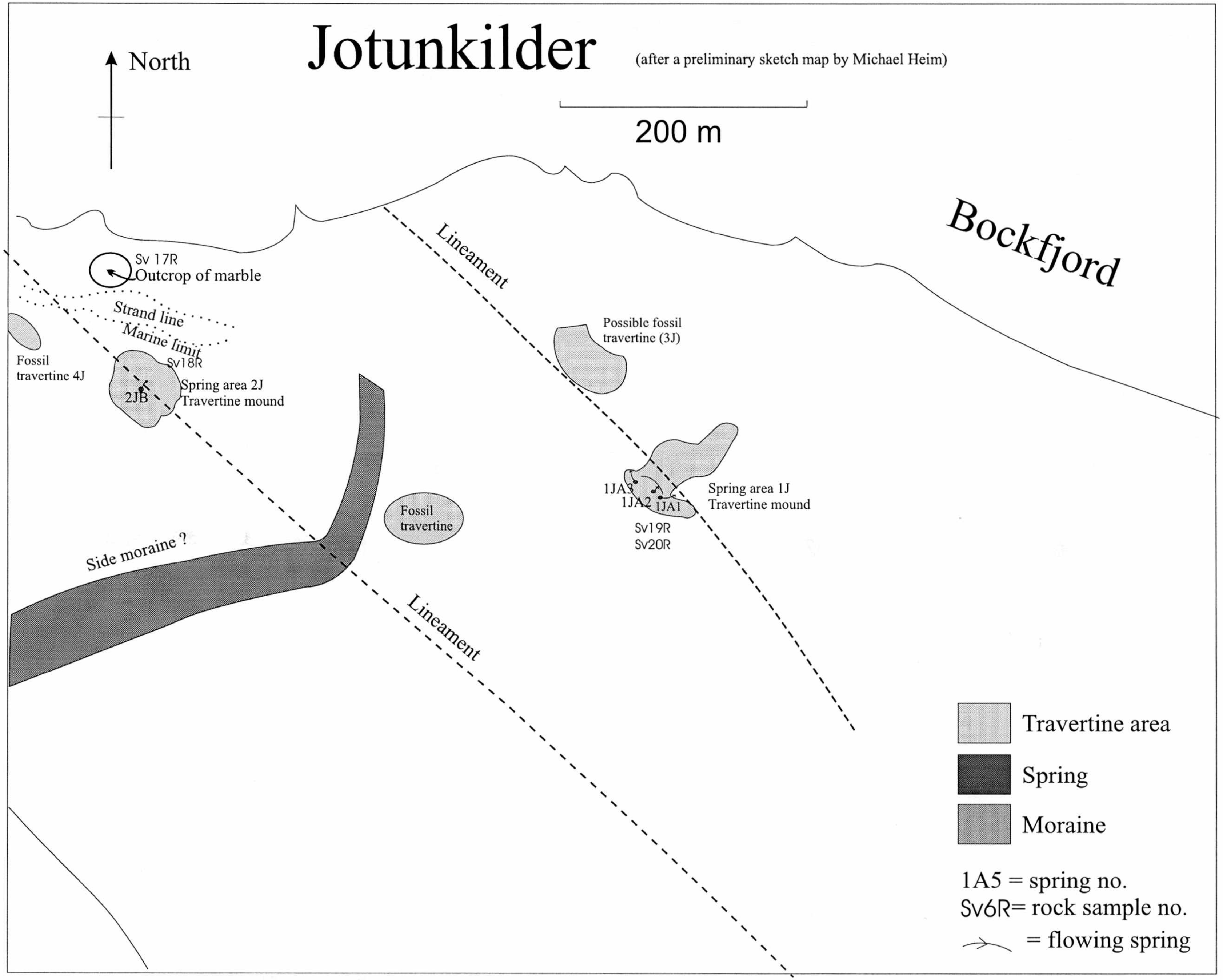
Appendix 8

Sketch maps illustrating spring location

Simplified versions of preliminary maps drawn by Michael Heim on the basis of field observations and interpretation of aerial photographs.

Appendix 8


Trollkildene
▨ Travertine area
■ Spring
▨ Moraine
1A5 = spring no.
Sv6R = rock sample no.
= flowing spring
Lineament
Fossil strand line (marine limit)
Side - Moraine Ridge
ca. Sv2R
ca. Sv1R
Sv4R, 5R, 6R
K2 (approx.)
1A1 1A2 1A3 1A5
1A4
2A1
2A2
2A3
2A4i
2A4ii
Sv9R
2A5
Sv13R
3A1
3A4
Sv15R
3A2
3A3
K1
4A1
Spring area 1
Terraced travertine
Spring area 2
Spring area 3
Travertine terraces
Sv10R
Sv11R
Solifluction with travertine crust
ca.Sv12R
Solifluction
Slipped blocky travertine
Spring area 4 Travertine
5A1
Spring area 5
Travertine terrace
ca. 5A2
ca. 5A3
Sv3
5A4
5A5
Travertine mound
Sv14R
Spring area 7
Fossil travertine
Sv7R
Spring area 6
6A2
6A1
Sv8R
5Dii
3Di
Peat
Sandur
Moraine
River flow
North
0 Scale 200 m



Jotunkilder (after a preliminary sketch map by Michael Heim)

Appendix 9

Results of radon analyses from Statens Strålevern (Prof. Terje Strand) in Bq/l

Sample numbers:	971-96	Spring 5A3	11:30 am 13/7/96
	972-96	Spring 5A3	11:33 am 13/7/96
	974-96	Spring K1	11:53 am 13/7/96
	975-96	Spring K1	11:55 am 13/7/96
	976-96	Spring 3A1	12:00 noon 13/7/96
	977-96	Spring 2A4ii	12:09 pm 13/7/96
	979-96	Spring 3A1	12:02 pm 13/7/96

Banks David

From: Terje Strand
To: David.Banks
Subject: vannprover - Svalbard
Date: 05. August 1996 09:07

Hei David!

Her er resultatene fra de 8 pr=F8vene fra Svalbard som vi har analysert:

971-96: 7 kBq/m3
972-96: 7 kBq/m3
974-96: 65 kBq/m3
975-96: 69 kBq/m3
977-96: 2 kBq/m3
976-96: 9 kBq/m3
979-96: 8 kBq/m3 =20

Som du ser er resultatene lave.

Med hilsen

Terje Strand